PERFORMANCE OF MODIFIED INHIBIT SENSE MULTIPLE ACCESS FOR PACKET SATELLITE COMMUNICATION

TRAN TUAN HUNG

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หัวข้อวิทยานิพนธ์	สมรรถนะของการเปลี่ยนแปลง ISMA สำหรับแพ็กเก็ตของการสื่อสารดาวเทียม
นักศึกษา	นาย ตุ๊ง ห่ม จัง
รหัสนักศึกษา	48060948
ปริญญา	วิศวกรรมศาสตรมหาบัณฑิต
สาขาวิชา	วิศวกรรมโทรคมนาคม
พ.ศ.	2550
อาจารย์ที่ปรึกษาวิทยานิพนธ์	ผศ.ดร. พิเชฐ ม่วงนวล

บทคัดย่อ

วิทยานิพนธ์ฉบับนี้ เสนอการประเมินสมรรถนะช่องสัญญาณดาวเทียมแบบแพ็คเก็ตที่ใช้การปรับปรุงโปรโตคอล np-ISMA ในระบบดาวเทียมชนิด LEO โดยโปรโตคอลนี้ดาวเทียมจะบอร์ดคาส สัญญาณไม่ว่าง เมื่อมีการรับแพ็คเก็ตที่เข้ามาเพื่อป้องกันการชนกันของข้อมูลที่ส่งมาจากสถานีภาคพื้นและบอร์ดคาสสัญญาณ Ideal เมื่อโปรโตคอลได้รับข้อมูลเรียบร้อยแล้ว เพื่ออนุญาตให้สถานีอื่นเข้ามาใช้งานต่อไป สัญญาณที่มาจากแต่ละสถานีภาคพื้นจะมีดีเลย์ในการแพร่กระจายคลื่นตามระยะระหว่างดาวเทียมและสถานีภาคพื้น โดยแต่ละสถานีภาคพื้นมีความน่าจะเป็นในการส่งแพ็คเก็ตได้สำเร็จเท่ากัน

จากผลการทดลองจะได้ว่าค่าพิสัยสามารถและดีเลย์ของโปรโตคอล np-ISMA ที่ชดเชยทางเวลา จะช่วยเพิ่มประสิทธิภาพของระบบได้มากกว่าโปรโตคอล np-ISMA ที่ไม่มีการชดเชยทางเวลาและมีประสิทธิภาพสูงกว่าโปรโตคอล slotted ALOHA.

Thesis Title : Performance of modified inhibit sense multiple access
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Student : Tran Tuan Hung
Student ID. : 48060948
Degree : Master of Engineering
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Thesis Advisor : Asst. Prof. Dr. Phichet Mongnoul

ABSTRACT

This thesis evaluates the packet satellite channel performance based on the modified non persistent Inhibit Sense Multiple Access Protocol (np-ISMA) protocol in the Low Earth Orbit (LEO) satellite system. In this protocol, the satellite station broadcasts a busy signal when an incoming packet is received, to inhibit other earth terminals from colliding transmissions, and broadcasts an idle signal when a packet is successfully received; to allow other earth terminals initiates packet transmission. These signals arrive at each earth terminal with a propagation delay, which is difference as the distance between the satellite station and the earth terminal, to consider that each earth terminal has an equally probability of successfully packet transmission.

Received results show that on the satellite uplink channel, the throughput and delay of np-ISMA protocol with timing advance are substantially improved when compared to without timing advance and the number of collided attempts and inhibited attempts are reduce as well. The throughput of modified np-ISMA protocol is also better than that of the slotted ALOHA protocol.

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Chapter 1

INTRODUCTIONS

1.1 Background

Packet satellite communications of future will be based on non-GEO satellite, in particular, "*Low Earth Orbit Packet Satellite System*", and will represent an interesting solution, since they are characterized by low propagation delay and low propagation attenuation that allow the use of low power earth stations. Packet satellite channels rely on appropriate access protocol to organize randomly occurring attempts by earth station, to transmit a data packet to a satellite, and offer the efficient sharing of communication resources by many contending earth station with unpredictable demand. The ALOHA system is one of the earliest random access protocols of packet over satellite channels, to provide a means of communication between a number of geographically distributed earth station and a satellite. The ALOHA protocol can be understood as when the earth stations transmit their packets over a common satellite channel without any mutual collision control or regulation. If two or more stations happen to transmit simultaneously, a packet 'collision' occurs. This mutual interference results in loss of packets, which have to be retransmitted.

In a satellite system, each earth station can hear its own packets repeated by the satellite and thus can determine whether a retransmission is necessary without waiting for an acknowledgement from the addresses. The likelihood of a collision during a retransmission can be reduced by having each station use a random number generator to determine the waiting period before retransmission. This decreases the probability that the same two packets will collide a second time without forcing any one station always to wait longer than the others before retransmitting.

However, the maximum throughput of ALOHA system is only 18.4 percent which is low channel utilization. In order to reduce the adverse effects of collisions, the simplest way for doing this is called slotted ALOHA. The slotted ALOHA protocol occurs when the satellite channel is slotted on time-axis and allows participating stations to transmit packets beginning only at specified times. Thus colliding packets interferes with the end of another is avoided. This doubles the utilization to 36.8 percent.

To reduce the adverse effects of collisions on ALOHA protocol, a number of alternative protocols have been proposed. The carrier sense multiple access (CSMA) protocol has been shown to be highly efficient in environments with propagation delays which are short compared to the packet transmission time. In essence, CSMA reduce the level of interference caused by overlapping packets in the random multi-access channel by allowing a terminal with a packet to be transmitted, first senses the channel for active carriers from other terminals. Only if the channel is idle, a new data packet is allowed to be transmitted, and inhibit transmission when the channel is in use. Packets which are inhibited or suffer rescheduled for transmission at a later time according to some rescheduling policy. In mobile radio systems, CSMA protocol has the drawback that collisions can occur if a terminal is not aware of an ongoing transmission by another remote terminal due to the distance between a terminal transmitting a data packet and the remote terminal which generating a data packet to transmit is very far or has the obstacles between them. This issue is discussed as the hidden terminal problem.

1.2 Object of the study

The slotted non persistent Inhibit Sense Multiple Access (np-ISMA) protocol is one of random access protocols, which is developed to solve the hidden terminal problem occurs in Carrier Sense Multiple Access (CSMA) protocol in packet switching radio network. In ISMA protocol the central base station continuously broadcasts the status of the inbound channel, being either IDLE or BUSY, to all terminals. The terminals transmit a data packet when receive an idle signal and schedule transmission when it receives inhibit signal. However, the increase of delay time in the np-ISMA protocol is more than that of CSMA protocol because all terminals detect only the channel status signal from the satellite and the satellite needs to receive packets from terminals and then broadcasts an inhibit signal to all of terminals. This situation is solved by the use of timing advance of idle signal, which is broadcasted to all terminals and reducing the idle signal broadcasting time is effect to reduce the idle sensing period. Therefore, the throughput and delay performance of modified np-ISMA system are increased.

Compare with the conventional slotted np-ISMA protocol, the modified slotted np-ISMA protocol can reduce the propagation delay effect on the BUSY and IDLE period of forward radio channel between the satellite and the stations. The throughput and delay performances are analyzed. It is shown that the proposed system is increased the throughput performance when increase the timing advance and decreased average delay time of a data packet. It is also shown that the time duration of idle sensing period is decreased and busy sensing period is increased.

This thesis is going to evaluate the modified slotted non-persistent ISMA protocol on a LEO packet satellite system. The process of evaluation, numerical analysis of throughput of the proposed system will be performed and compared with slotted ALOHA system.

1.3 The organization of the thesis

This thesis consists of five chapters:

Chapter 1: Introductions: introduces the study object of this thesis.

Chapter 2: Packet satellite system and multiple random access protocols: introduces some multi random access protocols which are used in packet satellite system.

Chapter 3: Modified Slotted non-persistent ISMA protocol in the packet satellite communications: introduces the proposed technique modified np-ISMA with timing advance in the LEO packet satellite system..

Chapter 4: Experiment results of modified slotted non persistent ISMA protocol on packet satellite communications: shows the results of the experiment which are done in the thesis.

Chapter 5: Conclusions.

Chapter 2

Packet Satellite System and Multiple Random Access Protocols

2.1 Packet Satellite System

2.1.1 General

Satellite communications [1-3] is a natural facility for serving user while they travel by various means. These include ships on the on oceans, rivers, and lake; commercial and private aircraft; land-based vehicles of various type; and individuals using portable and handheld devices. The mobile satellite service is an established user of spectrum at frequency between 1 and 3 GHz, where simple antennas provide flexible access to the space segment. This regime is preferred because of its greater ability to penetrate foliage and nonmetallic structures and bend around obstacles. (The low end of the useable spectrum is probably 100 MHz, which is able to penetrate the ionosphere under all conditions). Frequencies above 3GHz, while more readily available, are easily blocked by natural and manmade obstacles and introduce practical difficulties when it comes to generating transmit power. Above 10GHz, rain attenuation must be factored in the equation; as a result, there is an optimum window for MSS in the 1-to-3-GHz range. The MSS portion of the optimum is limited to segments of around 50MHz each due to the following factor:

- A general lack of bandwidth to begin with, due to the lower frequency as compared to C-, Ku-, and Ka- band;
- Competition with land-based services such as cellular telephone, mobile data communications, and a wide variety range of unlicensed services, the popular 802.11 wireless LAN being a notable examples;
- Reduces ability to achieve frequency reuse because user antennas have little or no gain and cannot easily discriminate among satellites within view.

Operations at 1.5 GHz (L-band) began in the 1970s with the launch of Marisat and subsequent creation of the most successful maritime mobile satellite operator: Inmarsat. However, 1990 was a turning point for MSS, when Motorola introduced their concept of a Low Earth Orbit Satellite System capable of directly serving handheld terminals. When the idea first appeared, the belief within the established GEO satellite industry was that even the most advanced satellites of the day were not capable supporting direct links to handheld phones. However, by 1994, several companies had devised schemes to provide mobile service handheld phones, employing literally all altitudes ranging from Iridium's 800 km all the way up to 36,000 km at GEO. Iridium went in to service around 1999, followed closely by Globalstar; however, neither service gained enough early subscribers to overcome the skepticism in the financial markets nor did both go in to bankruptcy. Iridium restructured in to a new company that provide basic voice and data service to government and industrial users. Globalstar was acquired by Craig McCaw and continues to seek its future as private company, focusing instead on aeronautical and fixed telephone services. Two GEO MSS systems began to offer similar service to handheld phones around 2002-AceS and Thuraya-and both have continued as operating businesses at the time of 2004. All of these systems are useable for fixed telephone and temporary emergency communications, which will have significant impact in areas and times of great need for rapid deployment and high mobility where the terrestrial infrastructure is either poor or nonexistent. Inmasat's fourth generation satellites could offer near-broadband services using a satellite similar in design to Thuraya.

2.1.2 Orbit selection

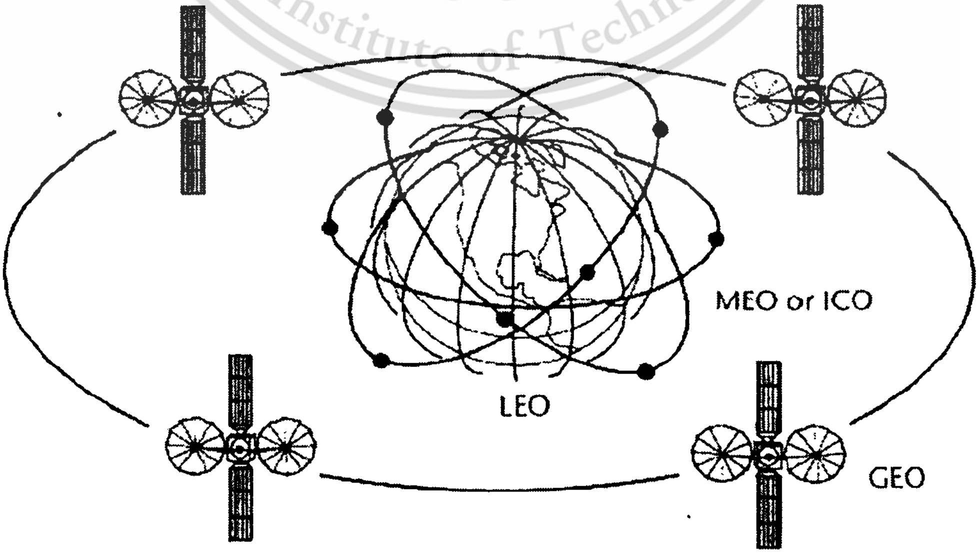

Figure 2.1 The three orbits that are applied to MSS: GEO, MEO, LEO

MSS systems involve mobile Earth stations, many of which do not employ directional antennas. The satellite need not to be stationary relative to the user, and thus inclined geosynchronous and non-GEO orbits are candidate. We mentioned Motorola's Iridium system that introduced the handheld UT. Motorola was joined by Loral and its Globalstar system and perhaps ICO Communications, a spin-off of Inmarsat, as implementers of non-GEO orbit constellations. While none of these original operations survived the tech wreck 2001, the non-GEO systems are interesting in their approach to reaching mobile users around the globe.

The general range of candidate orbits for use in a global MSS context is shown in Figure 2.1. The LEO constellation is exemplified by the Iridium system, which currently contains 66 satellites. The polar orbits of Iridium cause the satellites to provide the best coverage of the North and South Poles, with the least favorable operation occurring along the equator where only a single satellite is visible on the ground at a time. The other leading LEO system, Globalstar, contains a reduced number, 48, made possible by tilting the orbits to focus the coverage away from the poles and toward the regions of interest to more users. At a higher altitude, the MEO or intermediate circular orbit (ICO) provides coverage comparable to Globalstar but with fewer satellites. The satellites of ICO Communications, taking its name from the intermediate circular orbit they employ, also sec a larger amount of the Earth. A summary of the properties of these orbits is provided in Table 2.1

Table 2.1 Options for Earth Orbits for Use in Mobile and Other Satellite Communications Services

Orbit Definition	*Altitude Range (km)*	*Period (hours)*
LEO	150 to 1,000	1.5 to 1.8
MEO	5.000 to 10,000	3.5 to 6
Geosynchronous orbit	36,000 mean altitude	24
GEO	36,000 precisely, in plane of the equator	24
Highly elliptical Earth orbit (HEO)	1,000 to 4,000	12 to 24

2.2 MULTIPLE ACCESS TECHNIQUES

Efficient allocation of signaling dimensions between users is it key design aspect of both uplink and downlink channels, since bandwidth is usually scarce and/or very expensive. When dedicated channels are allocated to users it is often called multiple access. Applications with continuous transmission and delay constraints such as voice or video typically require dedicated channels for good performance to ensure their transmission is not interrupted. Dedicated channels are obtained from the system signal space using a channelization method such as time division, frequency division, code division or some combination of these techniques. Allocation of signaling dimensions for users with bursty transmissions generally use some form of random channel allocation that does not guarantee channel access. Bandwidth sharing using random channel allocation is called random multiple access or simply random access. In general, the choice of whether to use multiple access or random access - and which specific multiple or random access technique to apply - will depend on the system applications, the traffic characteristics of the users in the system, the performance requirements, and the characteristics of the channel and other interfering systems operating in the same bandwidth.

Multiple access techniques [4] divide up the total signaling dimensions into channels and then assign these channels to different users. The most common methods to divide up the signal space are along the time, frequency, and/or code axes. The different user channels are then created by an orthogonal or nonorthogonal division along these axes: time-division multiple access (TDMA) and frequency-division multiple access (FDMA) are orthogonal channelization methods, whereas code-division multiple access (CDMA) can be either orthogonal or nonorthogonal, depending on the code design. Directional antennas, often obtained through antenna array processing, add an additional angular dimension that can also be used to channelize the signal space; this technique is called space-division multiple access (SDMA). The performance of different multiple access methods depends on whether they are applied to an uplink or downlink as well as on their specific characteristics. The TDMA, FDMA, and orthogonal CDMA techniques are all equivalent in the sense that they orthogonally divide up the signaling dimensions and hence create the same number of orthogonal channel. As a result, all multiple access techniques that divide the signal space orthogonally have the same capacity when applied to additive white Gaussian noise (AWGN) channels. However, channel impairments such as flat and frequency-selective fading affect these techniques in different ways, which leads to different channel capacities and different performance in typical wireless channels.

2.2.1 Frequency-Division Multiple Access (FDMA)

In FDMA the system signaling dimensions are divided along the frequency axis into nonoverlapping channels, and each user is assigned a different frequency channel; see Figure 2.2.

The channels often have guard bands between them to compensate for imperfect filters, adjacent channel interference, and spectral spreading due to Doppler. If the channels are sufficiently narrowband, then the individual channels will not experience frequency-selective fading even if the total system bandwidth is large.

Transmission is continuous over time, which can complicate overhead functions such as channel estimation because these functions must be performed simultaneously and in the same bandwidth as data transmission; FDMA also requires frequency-agile radios that can tune to the different carriers associated with the different channels.

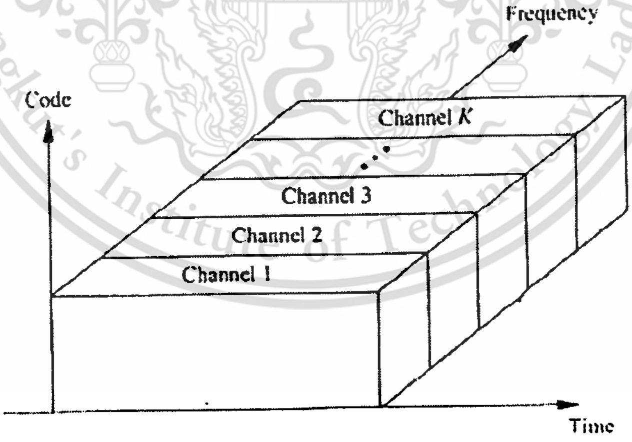

Figure 2.2 Frequency-division multiple access

It is difficult to assign multiple channels to the same user under FDMA, since this requires the radios to simultaneously demodulate signals received over multiple frequency channels. Even so, FDMA is the most common multiple access option for analog communication systems, where transmission is continuous, and serves as the basis for the AMPS and TACS analog cellular phone standards. Multiple access in OFDM systems, called OFDMA, implements FDMA by assigning different subcarriers to different users.

2.2.2 Time-Division Multiple Access (TDMA)

In TDMA, the system dimensions are divided along the time axis into nonoverlapping channels, and each user is assigned a different cyclically repeating timeslot; see Figure 2.3.

These TDMA channels occupy the entire system bandwidth, which is typically wideband, so some form of ISI mitigation is required. The cyclically repeating timeslots imply that transmission is not continuous for any user. Therefore, digital transmission techniques that allow for buffering are required. The fact that transmission is not continuous simplifies overhead functions such as channel estimation, since these functions can be performed during the timeslots occupied by other users. Time-division multiple access also has the advantage that it is simple to assign multiple channels to a single user by simply assigning him multiple timeslots.

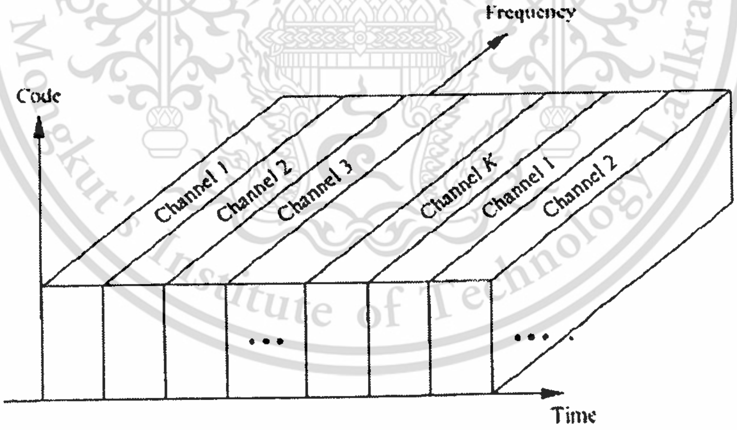

Figure 2.3 Time-division multiple access

A major difficulty of TDMA, at least for uplink channels, is the requirement for synchronization among the different users. Specifically, in a downlink channel all signals originate from the same transmitter and pass through the same channel to any given receiver. Thus, for flat-fading channels, if users transmit on orthogonal timeslots then the received signal will maintain this orthogonality. However, in the uplink channel the user transmit over different channels with different respective delays. To maintain orthogonal timeslots in the received signals, the different uplink transmitters must synchronize such that, after transmission through their respective channels, the received signals are orthogonal in time. This synchronization is typically coordinated by the base station or access point, and it can entail significant overhead. Multipath can also destroy time-division orthogonality in both uplinks and downlinks if the multipath delays are a significant fraction of a timeslot. Hence TDMA channels often have guard bands between them to compensate for synchronization error and multipath. Another difficulty of TDMA is that, with cyclically repeating timeslots, the channel characteristics change on each cycle. Thus, receiver functions that require channel estimates, like equalization, must re-estimate the channel on each cycle. When transmission is continuous the channel can be tracked, which is more efficient. Time-division multiple access is used in the GSM, PDC, and IS-136 digital cellular phone standards.

2.2.3 Code-Division Multiple Access (CDMA)

In CDMA the information signals of different users are modulated by orthogonal or nonorthogonal spreading codes. The resulting spread signal, simultaneously occupy the same time and bandwidth, as shown in Figure 2.4.

The receiver uses the spreading code structure to separate out the different users. The most common form of CDMA is multiuser spread spectrum with either direct sequence frequency hopping.

Downlinks typically use orthogonal spreading codes such as Walsh-Hadamard codes, although the orthogonality can be degraded by multipath. Uplinks generally use non-orthogonal codes owing to the difficulty of user synchronization and the complexity of maintaining code orthogonality in uplinks with multipath. One of the big advantages of nonorthogonal CDMA in uplinks is that little dynamic coordination of users in time or frequency is required, since the users can be separated by the code properties alone.

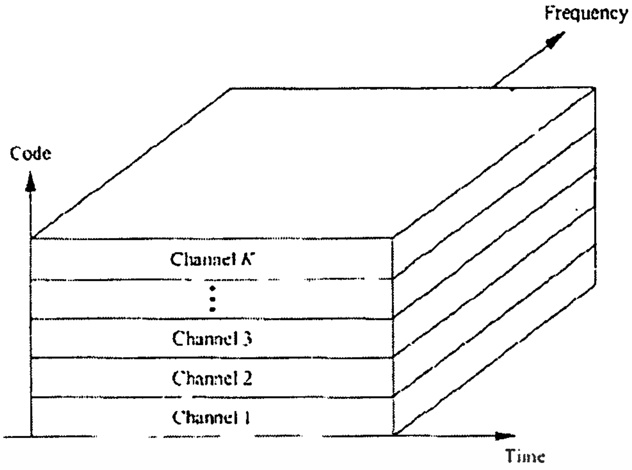

Figure 2.4 Code-division multiple access

In addition, since TDMA and FDMA carve up the signaling dimensions orthogonally, there is a hard limit on how many orthogonal channels can he obtained.

This is also true for CDMA using orthogonal codes, but if nonorthogonal codes are used then there is no hard limit on the number of channels that can be obtained. However, because nonorthogonal codes cause mutual interference between users, the more users that simultaneously share the system bandwidth using nonorthogonal codes, the higher the level of interference, which degrades system performance for all users. A nonorthogonal CDMA scheme also requires power control in the uplink to compensate for the near-far effect. The near-far effect arises in the uplink because the channel gain between a user's transmitter and the receiver is different for different users. Specifically, suppose that one user is very close to his base station or access point while another user is far away. If both users transmit at the same power level, then the interference from the close user will, swamp the signal from the far user. Thus, power control is used such that the received signal power of all users is roughly the same. This form of power control, which essentially inverts any attenuation and/or fading on the channel, causes each interferer to contribute an equal amount of power, thereby eliminating the near-far effect. Code-division multiple access systems with non-orthogonal spreading codes can also use MUD to reduce interference between users. Multiuser detection provides considerable performance improvement even under perfect power control, and it works even better when the power control is jointly optimized with the MUD technique. The form of CDMA with multiuser detection achieves the Shannon capacity of both the uplink and the downlink, although the capacity-achieving transmission and reception strategies for the two channels are quite different. Finally, it is simple to allocate multiple channels to one user with CDMA by assigning that user multiple codes. Code-division multiple access is used for multiple access in the IS-95 digital cellular standards, with orthogonal spreading codes on the downlink and a combination of orthogonal and nonorthogonal codes on the uplink. It is also used in the W-CDMA and CDMA2000 digital cellular standards.

2.2.4 Space-Division Multiple Access (SDMA)

Space-division multiple access uses direction (angle) as another dimension in signal space, which can be channelized and assigned to different users. This is generally done with directional antennas, as shown in Figure 2.5.

Orthogonal channels can be assigned only if the angular separation between users exceeds the angular resolution of the directional antenna. If directionality is obtained by using an antenna array, precise angular resolution require a large array, which may be impractical for the base station or access point and is certainly unfeasible in small user terminals. In practice, SDMA is often implemented using setorized antenna arrays. In these arrays, the 360° angular range is divided into N sectors.

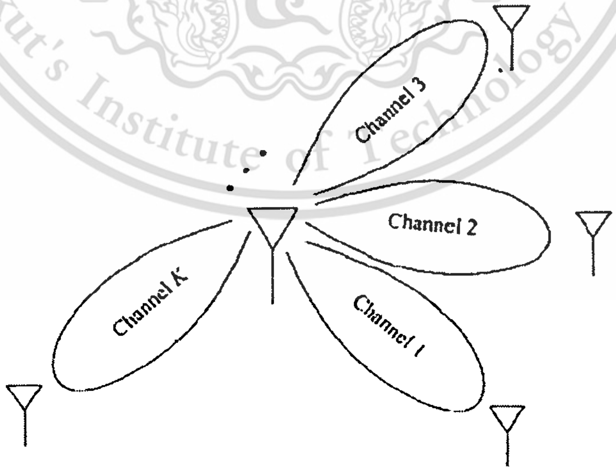

Figure 2.5 Space-division multiple access

There is high directional gain in each sector and little interference between sectors. Either TDMA or FDMA is used to channelize users within a sector. For mobile users, SDMA must adapt as user angles change; or, if directionality is achieved via sectorized antennas, then a user must be handed off to a new sector when it moves out of its original sector.

2.2.5 Hybrid Techniques

Many systems use a combination of different multiple access schemes to allocate signaling dimensions. OFDMA can be combined with tone hopping to improve frequency diversity. Direct-sequence spread spectrum (DSSS) can be combined with FDMA to break the system bandwidth into subbands; in this hybrid method, different users are assigned to different subbands with their signals spread across the subband bandwidth. Within a subband, the processing gain is smaller than it would be over the entire system bandwidth, so interference and ISI attenuation are reduced. In exchange for this performance loss, this hybrid technique does not require contiguous spectrum between subbands, and it also allows more flexibility in spreading user signals over different-size subbands depending on their requirements. Another hybrid method combines DS-CDMA with FH-CDMA so that the carrier frequency of the spread signal is hopped over the available bandwidth. This reduces the near-far effect because the interfering users change on each hop. Alternatively, TDMA and FH can be combined so that a channel with deep fading or interference is used only on periodic hops, enabling the mitigation of fading and interference effects via error correction coding. This idea is used in the GSM standard, which combines FH with its TDMA scheme in order to reduce the effect of strong interferers in other cells.

There has been much discussion, debate and analysis about the relative performance of different multiple access techniques for current and future wireless systems. Although analysis and general conclusions can be made for simple system and channel models, it is difficult to come up with a definitive answer as to the best technique for a complex multiuser system under a range of typical operating conditions. Moreover, simplifying assumptions must be made in order to perform a comparative analysis or simulation study, and these assumptions can bias the results in favor of one particular scheme. As with most engineering design questions, the choice of which multiple access technique to use will depend on the system requirements and characteristics along with cost and complexity constraints.

2.3 RANDOM ACESS TECHNIQUES

Multiple access techniques are primarily for continuous applications like voice and video, where a dedicated channel facilitates good performance. However, most data applications do not require continuous transmission: data are generated at random time instances, so dedicated channel assignment can be extremely inefficient. Moreover, most systems have many more total users (active plus idle users) than can be accommodated simultaneously, so at any given time channels can only be allocated to users that need them. Random access strategies are used in such systems to efficiently assign channels to the active users.

All random access techniques are based on the premise of packetized data or packet radio [5-12]. In packet radio, user data is colleted into packets of N bits, which may include error detection/correction and control bits. Once a packet is formed it is transmitted over the channel. Assuming a fixed channel data fate of R bps, the transmission time of a packet is $\tau = N/R$. The transmission rate R is assumed to require the entire signal bandwidth, and all users transmit their packets over this bandwidth with no additional signaling to separate simultaneously transmitted packets. Thus, if packets from different users overlap in times a collision occurs, in which case both packets may be decoded unsuccessfully. Packets may also be decoded in error as a result of noise or other channel impairments. The probability of a packet decoding error is called the packet error rate. Analysis of random access techniques typically assumes that, collectively, the users accessing the channel generate packets according to a Poisson process at a rate of λ packets per unit time; that is, λ is the average number of packets that arrive in any time interval $[0,t]$ divided by t. Equivalently, λN is the average number of bits generated in any time interval $[0,t]$ divided by t. For a Poisson process, the probability that the number of packet arrivals in a time period $[0,t]$, denoted as $X(t)$, is equal to some integer k is given by:

$$p(X(t)=k)=\frac{(\lambda t)^k}{k!}e^{-\lambda t} \tag{2.1}$$

Poisson processes are memoryless, so that the number of packet arrivals during any given time period does not affect the distribution of packet arrivals in any other time period. Note that the Poisson model is not necessary a good model for all types of user traffic - especially Internet data, where bursty data causes correlated packet arrivals.

The traffic load on the channel given Poisson packet arrivals at rate λ and packet transmission duration τ is defined as $G=\lambda\tau$. If the channel data rate is R_p packets per second then $\tau=1/R_p=N/R$ for R the channel data rate in bits per second. Note that G is unitless: it is the ratio of the packet arrival rate divided by the packet rate that can be transmitted over the channel at the channel's data rate R. We assume that colliding packets are always decoded in error. Thus, if $G>1$ then on average more packets (or bits) arrive in the system over a given time period than can be transmitted in that period, so systems with $G>1$ are unstable. If the transmitter is informed by the receiver about packets received in error and retransmits these packets, then the packet arrival rate λ and corresponding load $G=\lambda\tau$ is computed based on arrivals of both new packets and packets that require retransmission. In this case G is referred to as the total offered load.

Performance of random access techniques is typically characterized by the throughput S of the system. The throughput, which is unitless, is defined as the ratio of the average rate of packets successfully transmitted divided by the channel packet rate R_p. The throughput thus equals the offered load multiplied by the probability of successful packet reception, $S=G_p$ (successful packet reception), where this probability is a function of the random access protocol in use as well as the channel characteristics, which can cause packet errors in the absence of collisions. Thus $S<G$. Also, since a system with $G>1$ is unstable, stable systems have $S\leq G\leq 1$. Observe that the throughput is independent of the channel data rate R, since the load and corresponding throughput are normalized with respect to this rate. This allows analysis of random access protocols to be generic any underlying link design or channel capacity. For a packet radio with a link data rate of R bps, the effective data rate of the system is RS, since S is the traction of packets or bits successfully transmitted at rate R. The goal of a random access method is to make S as large as possible in order to fully utilize the underlying link rates. Note that in some circumstances overlapping packets do not cause a collision. In particular, short periods of overlap between colliding packets, different channel gains on the received packets, and/or error correction coding can allow one or more packets to be successfully received even with a collision. This is called the capture effect.

Random access techniques were pioneered by Abramson with the ALOHA protocol, where data is packetized and users send packets whenever they have data to send. ALOHA is extremely inefficient owing to collisions between users, which lead to very low throughput. The throughput can be doubled by slotting time and synchronizing the users, but even then collisions lead to relatively low throughput values. Modifications of ALOHA protocols to avoid collisions and thereby increase throughput include carrier sensing, collision detection, and collision avoidance. Long bursts of packets can be scheduled to avoid collisions, but this typically takes additional overhead. In this section we will describe these various techniques for random access, their performance, and their design trade-offs.

2.3.1 Basic ALOHA channel:

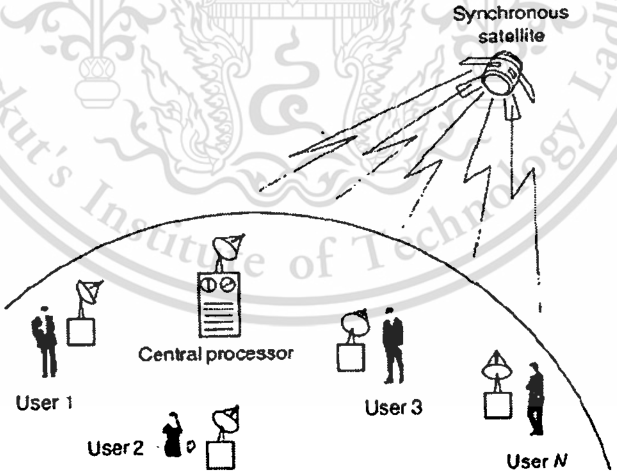

Figure 2.6 Distributed network using a satellite channel for common access

First of all, ALOHA [13] is not an acronym. Used in the sense of its Hawaiian meaning as a greeting both of arrival and of departure, it is the name of a communications protocol and technique that was developed during the late 1960s at the University of Hawaii. The word is also used in the operation of the protocol: Whenever a user has something to transmit, he simply says "Aloha" into the channel and begins transmitting the message.

Imagine the situation illustrated in Figure 2.6. Here we see a group of users, each communicating with a central processor over a commonly available channel. The communication takes places via a synchronous satellite 22,300 miles above the equator. All users can receive the communications of all other users, and can also hear their own transmissions. The satellite is more than just a mirror in the sky. It receives signals transmitted on the uplink frequency, amplifies them, and retransmits them on it different downlink frequency. Because of the long distance the transmissions must travel, it takes about one-fourth of a second for a user's signal to reach the satellite and be returned to earth.

Figure 2.7 shows the typical occurrences in the channel. Although the ALOHA technique is not confined to any particular data rate, it is explained most easily in terms of a specific data rate. We will assume that the channel is operating at a rate of 50,000 bits per second, and that each user sends a data packet consisting of 1000 bits or less. A full packet will thus have duration on the channel of one-fiftieth of a second (20 ms), which is relatively short compared to the quarter second (250 ms) that the packet takes to travel up to the satellite and back.

This figure shows each individual user's transmissions separately and the sum of all the user transmissions. User I transmits a packet for 20 ms first. Shortly thereafter user N transmits a packet, but before this packet is completed, user 2 begins to transmit a packet. As we see in the sum channel, this results in a collision, or overlap, of these two packets, making both of them unintelligible at the destination.

One-quarter second after the initial transmission, user 2 and user N, by listening to the satellite downlink, hear that their packets have been involved in a collision. They each transmit a repetition packet to replace the packet that was damaged in the collision. (We assume that, if any part of a packet is damaged, the entire packet has to be repeated.) If both users act immediately, however, they are likely to collide again. In order to avoid this, both users wait for a randomly selected delay time to elapse before attempting the retransmission. As we see in Figure 2.7, the procedure is successful: The repetitions of the collided packets are retransmitted without interference.

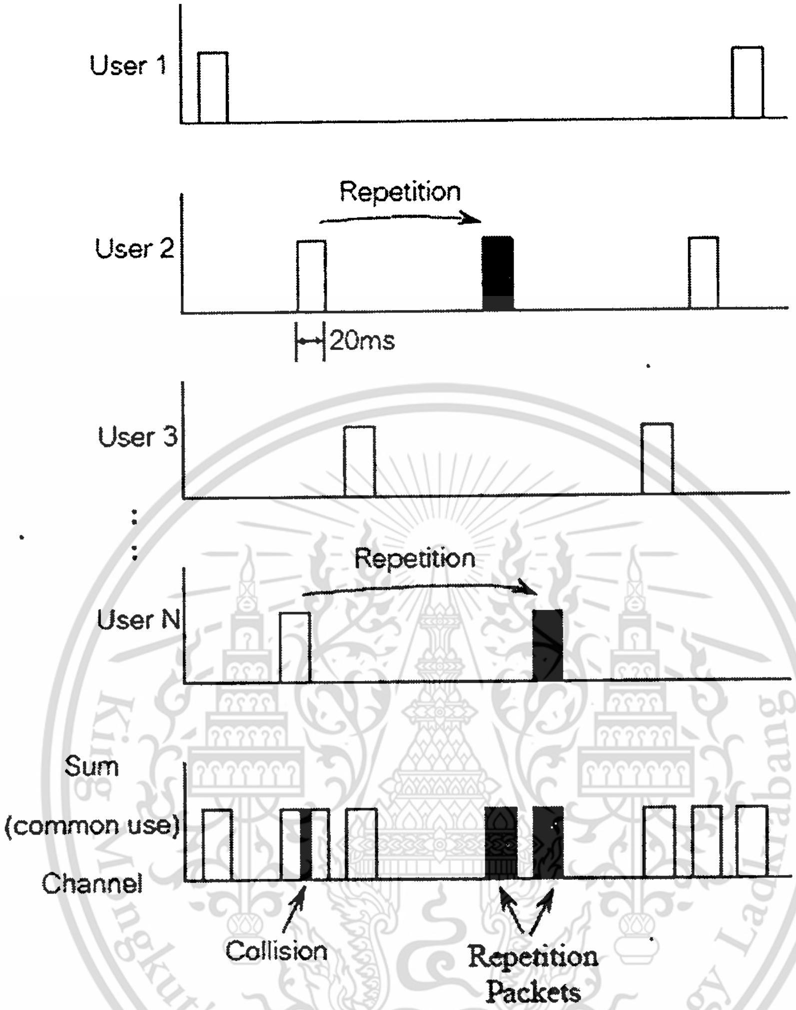

Figure 2.7 Summary operation of the basic ALOHA channel

In order to portray the packet overlap process, we have had to use a time scale for Figure 2.7 that is quite inaccurate. The entire width of the figure represents less than 1 second of real time. In reality it is very unlikely- for most users quite impossible- that any user will generate more than one packet during an l-second interval. (To do so from a keyboard-type device would require a typing speed in excess of 1500 words per minute.)

With the offered traffic G, the throughput can be found as

$$S = Ge^{-2G} \tag{2.2}$$

In any case, collisions do occur, causing delays and retransmissions. As the number of active users increases or the frequency with which each user transmits packets increases, the likelihood of collisions increases. As the collisions increase, the channel becomes even busier because each collision generates at least two attempted retransmissions. Therefore, it is important to see if we can predict the behavior of the ALOHA channel and determine how much traffic the channel is actually capable of delivering.

2.3.2 The slotted ALOHA channel:

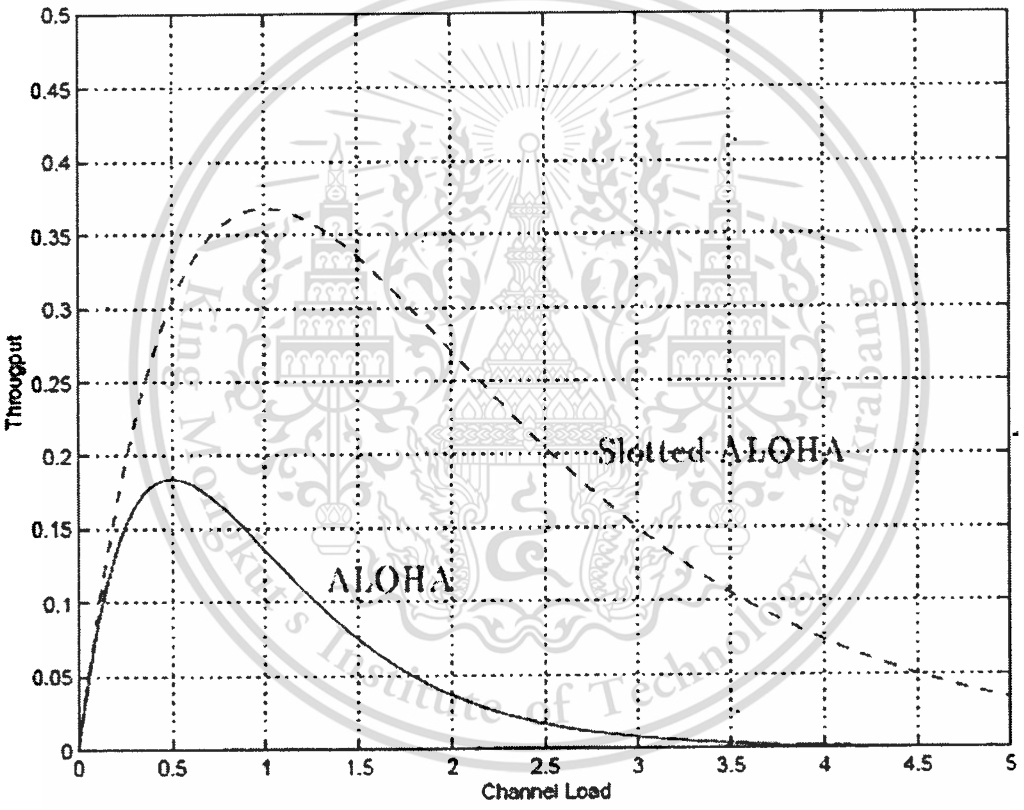

Figure 2.8 Throughput of ALOHA and Slotted ALOHA channels

In slotted ALOHA [14], time is assumed to be slotted in timeslots of duration τ, and users can only start their packet transmissions at the beginning of the next timeslot after the packet has formed. Thus, there is no partial overlap of transmitted packets, which increases throughput. Specifically, a packet transmitted over the time period $[0,\tau]$ is successfully received if no other packets are transmitted during this period. This probability is obtained with $t=\tau$:

with G is the offered traffic. The corresponding throughput is :

$$S = Ge^{-G} \tag{2.4}$$

Slotted ALOHA has double the maximum throughput as pure ALOHA, and it achieves this maximum at a higher offered load. Although this represents a marked improvement over pure ALOHA, the effective data rate is still less than 40% of the raw transmission rate. This is extremely wasteful of the limited wireless bandwidth, so more sophisticated techniques are needed to increase efficiency.

Note that slotted ALOHA requires synchronization of all nodes in the network, which can entail significant overhead. Even in a slotted system, collisions occur whenever two or more users attempt transmission in the same slot. Error control coding can result in correct detection of a packet even after a collision, but if the error correction is insufficient then the packet must be retransmitted.

2.3.3 Carrier-Sense Multiple Access Protocol (CSMA)

Collisions can be reduced by carrier-sense multiple access protocol [15], where users sense the channel and delay transmission if they detect that another user is currently transmitting. To be effective, detection time and propagation delays in the system must be small. After sensing a busy channel, a user typically waits a random time period before transmitting. This random back-of precludes multiple users simultaneously transmitting as soon as the channel is free. Carrier-sense multiple access works only when all users can detect each other's transmissions and the propagation delays are small. Wired LANs have these characteristics, so CSMA is part of the Ethernet protocol. However, the nature of the wireless channel may prevent a given user from detecting the signals transmitted by all other users. This gives rise to the hidden terminal problem [16-18] (illustrated in Figure 2.9), whereby each node can hear its immediate neighbor but no other nodes in the network. In the figure, node 3 and node 5 each wish to transmit to node 4. Suppose node 5 starts its transmission. Since node 3 is too far away to detect this transmission, it assumes that the channel is idle and begins its transmission, thereby causing a collision with node 5's transmission. Node 3 is said to be "hidden" from node 5 because it cannot detect node 5's transmission.

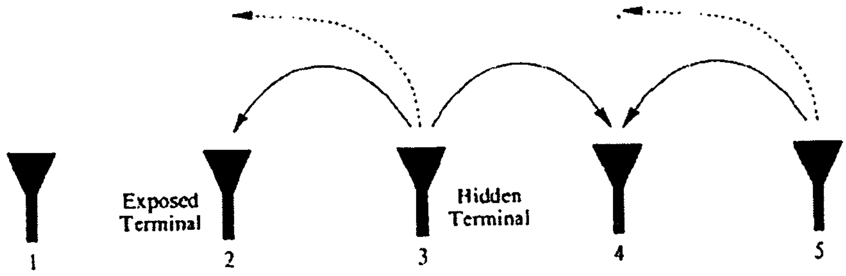

Figure 2.9 Hidden and exposed terminals

ALOHA with CSMA also creates inefficiencies in channel utilization from the exposed terminal problem, also illustrated in Figure 2.9. Suppose the exposed terminal in this figure - node 2 - a wish to send a packet to node 1 at the same time that node 3 is sending to node 4. When node 2 senses the channel it will detect node 3's transmission and assume the channel is busy, even though node 3 does not interfere with the reception of node 2's transmission by node 1. Thus node 2 will not transmit to node 1 even though no collision would have occurred.

The collisions introduced by hidden terminals are often avoided in wireless networks by a four-way handshake prior to transmission. This collision avoidance is accomplished as follows. A node that want, to send a data packet will first wait for the channel to become available and then transmit a short RTS (request to send) packet. The potential receiver, assuming it perceives an available channel, will immediately respond with a CTS (clear to send) packet that authorizes the initiating node to transmit and also informs neighboring hidden nodes (i.e., nodes that are outside the communication range of the transmitter but within the communication range of the receiver) that they must remain silent for the duration of the transmission. Nodes that overhear the RTS or CTS packet will refrain from transmitting over the expected packet duration. A node can send an RTS packet only if it perceives an idle channel and has not been silenced by another control packet. A node will transmit a CTS packet only if it has not been silenced by another control packet. The RTS/CTS hand shake is typically coupled with random backoff to avoid all nodes transmitting as soon as the channel becomes available. In some incarnations, including the 802.11 WLAN standards, the receiver sends an ACK (acknowledgement) packet back to the transmitter to verify when it has correctly received the packet, after which the channel again becomes available.

Another technique to avoid hidden terminals is busy-tone transmission. In this strategy, users first check to see whether the transmit channel is busy by listening for a "busy tone" on a separate control channel. There is typically not an actual busy tone; instead, a bit is set in a predetermined field on the control channel. This scheme works well in a flat network without centralized control; more complicated measures are used to ensure that any potential interferer on the first channel can hear the busy tone on the second. Hybrid techniques using handshakes, busy-tone transmission, and power control can also be used. Collisions can also be reduced by combining DSSS with ALOHA. In this scheme, each user modulates his signal with the same spreading code, but if user transmissions are separated by more than a chip time, the interference due to a collision is reduced by the code autocorrelation.

2.3.4 Inhibit Sense Multiple Access protocols (ISMA)

With Inhibit Sense Multiple Access protocols (ISMA) [19-24], each user must be able to detect the transmission of all other users. There is a base station that transmits a busy/idle signal on separate channels (inbound and outbound) to indicate the presence or absence of a transmission of one of the users. As soon as the base station receives a transmission from a user on the inbound channel, it will generate a busy signal on the outbound channel. When the transmission ends, the base station transmits an idle signal. Now, if two users are hidden from each other, they will still be able to determine if the other user is transmitting or not because the base station: The variations on the ISMA scheme are due to the behavior of users that wish to transmit and find (by sensing) the channel busy. One of the variations is Slotted ISMA with Collision Detection. In this group of protocols the throughput is the ratio between the expected useful times spent in a cycle to the cycle duration itself. To improve the throughput, the cycle length must therefore be reduced. A cycle is composed of a transmission period followed by an idle period. Shortening the idle period is possible by means of Slotted 1-persistent ISMA protocols, which do not perform very well under most loads. The duration of the successful transmission periods should not be changed for this is the time the channel is used best. Hence, performance can be improved by shortening the duration of unsuccessful transmission periods.

2.3.5 Non-persistent ISMA (np-ISMA)

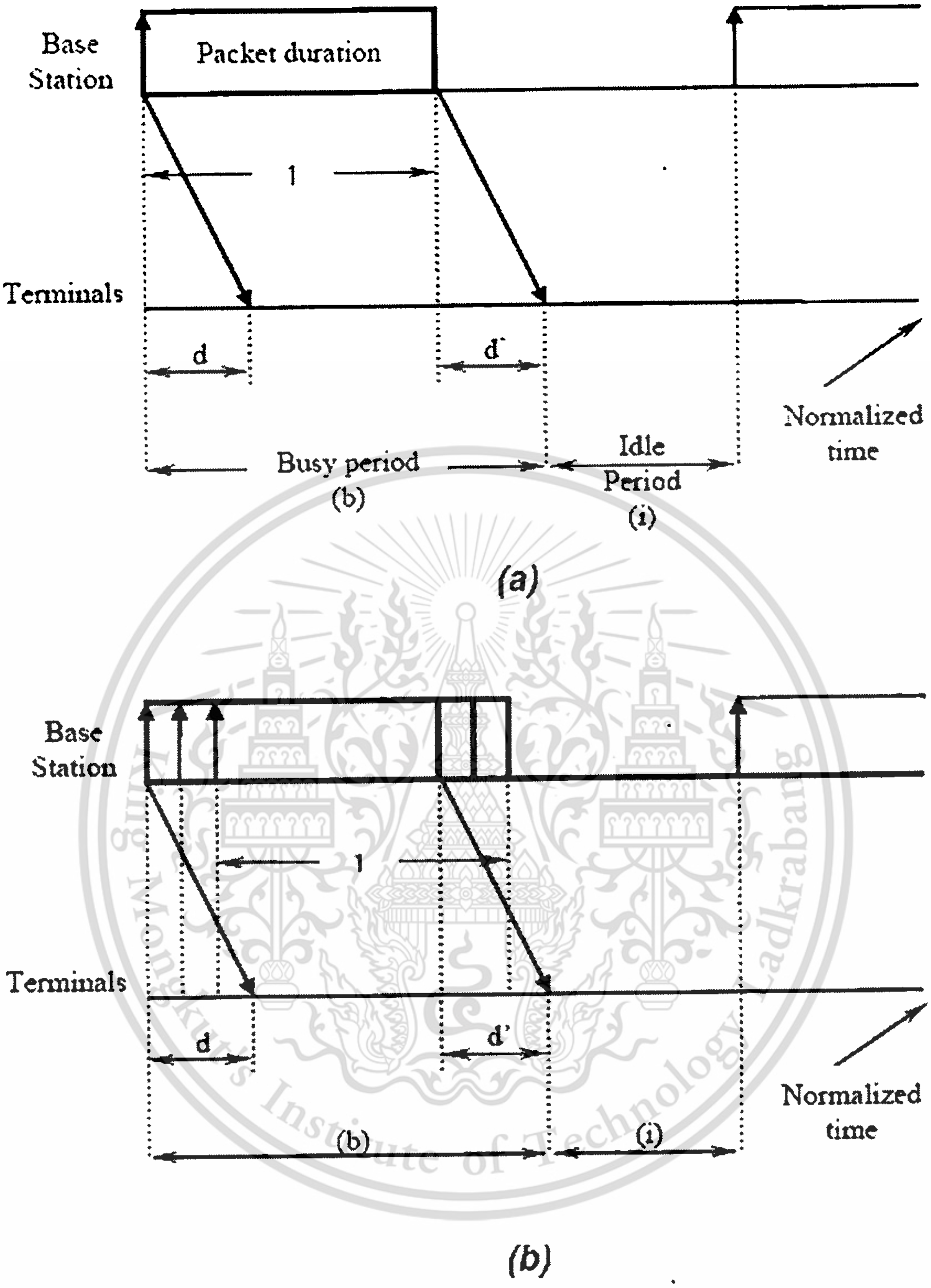

Figure 2.10 (a): Successful transmission

(b): Unsuccessful transmission

The operation of a ready mobile packet radio terminal in a non-persistent ISMA channel can be briefly described as follows:

(a). If the inbound multiple-access channel is idle, the mobile terminal transmits the packet.

(b). If the inbound channel is busy, the terminal schedules the transmission of the packet to some later time according to the retransmission delay distribution. At the retransmission time, depending on the idle/busy state message broadcast by outbound channel, the terminal repeats the algorithm as explained.

Successful and unsuccessful transmissions in ISMA are illustrated in Figure 2.10. The inhibit delay fraction is shown in Figure 2.10a by notation d and the fraction of time required to reverse this condition (i.e. from busy state to free state) is represented by d'. In the following analysis it is assumed that $d = d'$ for simplification. Thus mobile terminals are inhibited from transmission until the inbound channel is free, hence preventing most packet collisions. The inhibited packets are rescheduled. In the present analysis, it is further assumed that in the event of collision, instead of unsuccessful transmission as shown in Figure 2.10b, one of the involved packets (test packet) may be received successfully if its received power P_d exceeds the total power P_{ni} of all interfering packets by a factor known as the capture ratio (z_0).

The throughput S is defined as the ratio of the probability of success of the test packet $P_{success}(z_0)$, and expected length of the cycle L_C, assuming that the total arrival rate of (new plus inhibited, rescheduled) packets, G, is Poisson-distributed:

$$S \underline{\Delta} \frac{P_{success}(z_0)}{\overline{L}_C} \tag{2.5}$$

Where the expected length of a cycle L_C is defined as the sum of a busy period and the following idle period:

$$\overline{L}_C \underline{\Delta} 1 + 2d + \frac{1}{G} e^{-dG} \tag{2.6}$$

$$P_{success}(z_0) = \sum_{n=0}^{\infty} [P_n (n+1) prob\{p_d / p_{ni} > z_0\}] \tag{2.7}$$

And P_n, the probability of n interfering packets overlapping a test packet, is given by:

$$P_n = \frac{(dG)^n}{n!} e^{-dG} \tag{2.8}$$

2.3.6 Slotted Non-persistent ISMA (Slotted np-ISMA)

We assume that all terminals have the same characteristics, except their relative positions. Data Packets arrive at the terminals generated by the users. The transmission occurs only when the terminal gets permission to transmit. When there is a busy signal, transmission attempts are unsuccessful. Such packets are rescheduled for later by putting them into retransmitting buffer, which will transmit-again at the start of the next idle time slot and the duration of a time slot is assumed to be exactly to the transmission time of a single packet. Thus, there is either no collision or complete collision of the packets. Since there is no collision detection, a higher level process is needed to determine which packets were lost due to this complete collision and need to be retransmitted. A terminal in the blocked state will listen to the busy signal transmitted by the base station to determine when the channel becomes idle.

Each terminal of slotted np-ISMA is restricted to start transmission only at the beginning of a time slot and the duration of a time slot is assumed to be exactly to the transmission time of a single packet. Thus, there is either no collision or complete collision of the packets in which case an unsuccessful packet will be subsequently retransmitted after a random number of slots.

In order to prevent these collisions among data packets transmitted from mobile terminals to common base station, the inbound multiple access channels can be supplemented by a broadcast inhibit-signaling channel. The inhibit bits indicate the state of the inbound channel: busy or idle. The moment when the base station receives an inbound packet, the outbound signaling channel broadcasts the busy condition to all terminals. A fraction of the constant packet length is needed to inhibit the mobile packet transmissions, the inhibit delay fraction d is a dimensionless quantity. Thus mobile terminals are inhibited from transmission until the inbound channel is free, thus preventing collisions. These packets are rescheduled according to retransmission distribution. Inhibit delay fraction, d, is defined as the ratio of propagation delay and packet timing.

The length of an idle period (I) is at least one time slot. When the idle period is only one slot long, it means there is at least one arrival in the first slot of the idle period. For the period to be two slots long means that there is no arrival at the first slot, but there is at least one arrival in its second slot. The virtual offered traffic on the forward channel, assume Poisson with average value G, consists of both new packet arrivals and rescheduled packets from both collisions and inhibited transmissions. With slotted non-persistent ISMA, the normalized slot length is set just slightly greater than $d/2$. It allows terminals to commence transmitting packets only at slot boundaries, thereby reducing collisions and resulting in higher throughput. Continuing the reasoning and considering the Poisson scheduling process we have:

$$I = \frac{d}{1-e^{-dG}} \tag{2.9}$$

A collision might occur if two or more packets arrive within the same slot and are scheduled for transmission in the next slot. A busy period will contain k transmission periods if there is at least one arrival in the slot of each of the first $k-1$ transmission periods, and no arrival in the last slot of the k^{th} transmission period. Thus, the busy period is

$$B = \frac{1+d}{e^{-dG}} \tag{2.10}$$

The average successful packet transmission time in a cycle is found as,

$$\overline{U} = \frac{\overline{B}}{1+(d-a)} P_{succ} \tag{2.11}$$

Where P_{succ} is the probability of a successful transmission period. We have:

$$P_{succ} = \frac{Prob[single\ arrival\ within\ a\ slot]}{Prob[more\ arrivals\ within\ a\ slot]} = \frac{dGe^{-dG}}{1-e^{-dG}} \tag{2.12}$$

Put all these together, we get the average throughput is

$$S = \frac{U}{B+I} = \frac{dGe^{-dG}}{1+d-e^{-dG}} \tag{2.13}$$

The packet delay which followed the quasi-static assumption of offered traffic is applied to the slotted non-persistent ISMA protocol. There are three components of packet delay:

1) When a data packet is successfully received, the normalized delay by the packet length is denoted by

$$D_s = 1 + d \tag{2.14}$$

2) When a data packet is unsuccessfully received due to a collision and retransmits until successfully received, the delay consists of the transmission time of the packet is $1+(d-a)$, the average propagation delay is $d/2$, the transmission time of the acknowledgement packet is T_a, and the average retransmission delay is T_c, that is

$$D_r = N_c\left(1 + d + T_a + T_c\right) \tag{2.15}$$

which normalized by the packet length, where N_c is the average number of unsuccessful transmission attempts (collisions) a packet encounters before being successfully delivered.

3) When the forward channel is busy, the delay is

$$D_i = N_i T_r \tag{2.16}$$

where N_i is the average number of inhibited attempts before successful transmission packet, and T_r is the average retransmission wait time.

The expression for the average packet delay for slotted non-persistent ISMA is

$$\overline{D} = 1 + d + N_c\left(1 + d + T_a + T_c\right) + N_i T_r \tag{2.17}$$

The average number of collided attempts can be found as

$$N_c = \frac{(H-S)}{S} \tag{2.18}$$

The average number of inhibited attempts can be found as

$$N_i = \frac{(G-H)}{S} \tag{2.19}$$

where H is the rate of actual transmissions on the channel. For slotted non-persistent ISMA

$$H = H_S(d,G) = \frac{dG^2 e^{-dG}}{1-e^{-dG}} \tag{2.20}$$

Thus, we are able to determine the average packet delay time as a function of either the virtual traffic, or the throughput.

2.3.7 Slotted 1-persistent ISMA (Slotted 1p-ISMA)

In np-ISMA there are situations in which the channel is idle although one or more users have packets to transmit. The 1-persistent ISMA (1p-ISMA) is alternative to np-ISMA that avoids such situations. When the outbound channel sends the busy signal to the terminal, it persists to wait and transmits as soon as the channel becomes idle. Thus the channel is always used if there is a user with a packet.

The analysis of slotted 1p-ISMA is similar to slotted np-ISMA. The mean of idle period is same as in slotted np-ISMA. Since the busy period will contain k transmission periods if at least one packet arrives in each of the first $k-1$ transmission periods and no packets arrives in the k^{th} transmission period. So the busy period B is

$$B = \frac{1+d}{e^{-G(1+d)}} \tag{2.21}$$

The probability of success in the first transmission period in a busy period, P_{SUC1} is different from the success probability in any other transmission period within the busy period, P_{SUC2}. For the first transmission period in a busy period to be successful we need the last slot of the idle period to contain exactly one arrival, taking in account that there is at least one arrival there, since it is the last slot. Hence

$$P_{SUC1} = \frac{dGe^{-dG}}{1-e^{-dG}}. \tag{2.22}$$

For any transmission period in a busy period to be successful we must have exactly one arrival during the previous transmission period,

$$P_{SUC2} = \frac{G(1+d)e^{-G(1+d)}}{1-e^{-G(1+d)}} \tag{2.23}$$

The channel carries useful information only during successful transmission periods. P_{SUC1} is the expected amount of time the channel carries useful information during these period and P_{SUC2} is the probability of success in each of these transmission periods. The expected amount of time within a cycle that the channel carries useful information is:

$$U = P_{SUC1} + \frac{B-(1+d)}{1+d} P_{SUC2}\ . \tag{2.24}$$

Therefore the throughput can be given by:

$$S = \frac{Ge^{-G(1+d)}(1+d-e^{-dG})}{(1+d)(1-e^{-dG})+de^{-G(1+d)}} \tag{2.25}$$

2.3.8 Slotted Non-persistent ISMA with Collision Detection (Slotted np-ISMA\CD)

The operation of Slotted ISMA\CD protocols is identical to the operation of the corresponding ISMA protocols, expect that if a collision is detected during transmission by the base station, the transmission is aborted and the packet is scheduled for later transmission. The non-persistent ISMA\CD time alternates between busy periods (which include both successful and unsuccessful transmission periods) and idle periods. The length of the busy period is B

$$B = \frac{P_{SUC}(1+d)+(1-P_{SUC})(\gamma+d)}{e^{-dG}} \tag{2.26}$$

Where P_{SUC} is the probability of a successful transmission period

$$P_{SUC} = \frac{Gde^{-dG}}{1-e^{-dG}} \tag{2.27}$$

And γ is the time taken to complete a successful transmission of a user

$$\gamma = 2d + d_{CD} + d_{cr} \tag{2.28}$$

d_{CD} is the time taken by the base station to detect a collision and dc, is the time taken to let the other users know that a collision took place.

The distribution of the idle period is identical to that computed for Slotted np-ISMA, thus the expected length of the idle period is

$$I = \frac{d}{1-e^{-dG}} \tag{2.29}$$

Amount of time within a cycle during which the channel carries useful information is

$$U = \frac{P_{SUC}}{e^{-dG}} \tag{2.30}$$

Combining the equations throughput can be analyzed

$$S = \frac{dGe^{-dG}}{dGe^{-dG} + (1+e^{-dG} - dGe^{-dG})\gamma + d} \tag{2.31}$$

$\gamma = 1$, throughput is identical to Slotted np-ISMA.

Chapter 3

Modified Slotted non-persistent ISMA protocol in the packet satellite communications

3.1 Modified Slotted non-persistent ISMA protocol

The Modified Slotted non-persistent ISMA protocol can be proposed to decrease effect of propagation delay by reducing the empty period of idle and busy slot on forward channel.

Now we can revise the Slotted np-ISMA. Slotted np-ISMA can be considered in which the time-axis is slotted and the slot size is different between idle and busy slot. The base station and the terminals are synchronized and are forced to start transmission only at the beginning of a slot. When a packet's arrival occurs during a slot, the terminal waits for the channel status signal at the beginning of the next slot and operates according to the protocol as described before. Figure 3.1 illustrates the timing relationship in slotted non-persistent ISMA.

A cycle starts at t0 by starting of idle signal from a base station. The average time between the beginning of a packet transmission and the detection of a busy status by the remaining terminals is the inhibit time denoted by d, which is twice that of average of the propagation delay. Therefore, an idle signal reaches at terminals with time t0+d/2. For simplicity, assume that the average of inhibit time is normalized to a unity packet length.

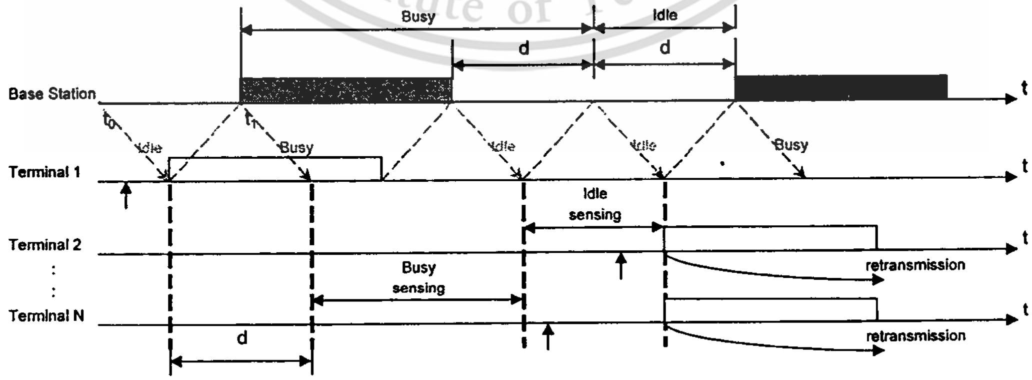

Figure 3.1 Time relationships in slotted non-persistent ISMA protocol

The ready terminals transmit a data packet to the base station at time t0+d/2, reaches at the base station at time t0+d = t1. Then, the base station broadcasts an inhibit signal, reaches the terminal at time t1+d/2 and successfully received a data packet at t1+1. The base station broadcasts an idle signal and reaches the terminal at time t1+1+d/2. Any terminal is ready to transmit between t1+d/2 and t1+1+d/2, are inhibited to transmit and reschedule its data packet, and if ready between t1+1+d/2 and t1+1+3d/2, are permitted to transmit on the next slot. The slot has received a packet, is called busy slot and no receive a packet is called idle slot. The average duration of the idle and busy slot are denoted by $\overline{I}$ and $\overline{B}$, respectively, alternates in the forward channel transmissions. The forward channel is busy when one or more packets are presence. If more than one terminal transmit packet in the same idle slot, the collision is occurring, with non-capture effect, both of data packets are destructive and retransmit at a later time. The duration of each packet is set to the unit of time, which is 1. When the reception of the last interfering packet terminates, the base station broadcasts idle signal at the next time slot and the next cycle starts. If one terminal transmitted a data packet in the idle slot, successfully transmission and the base station broadcasts an idle signal immediately.

In the **Modified Slotted non-persistent ISMA protocol**, we add the timing advance to channel status signals to decrease effect of propagation delay by reducing the empty period of idle and busy slot on forward channel. The average duration of the timing advance is denoted by a, which normalized to a unity packet length.

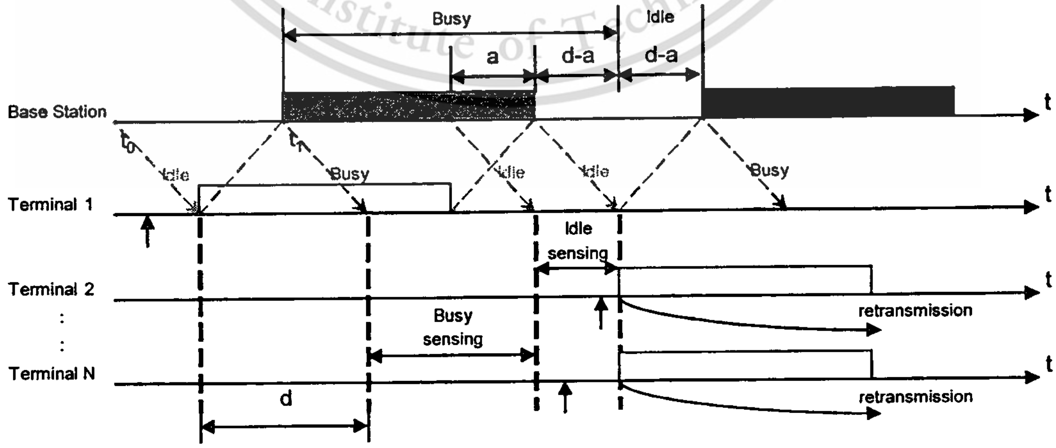

Figure 3.2 Timing relationships in modified slotted non-persistent ISMA protocol

Figure 3.2 illustrates the timing relationship in the modified slotted non-persistent ISMA with timing advance. Result in the empty duration of busy and idle slots are reduced to d-a. A cycle starts at the base station receiving a data packet, before it received the successfully at t1+1- a, the base station broadcast an idle signal to all terminals to permit the transmission, and then broadcast an inhibit signal before successfully received a data packet if 2a-d is positive value or after the successfully received if 2a-d is negative value. An inhibit signal is broadcasted at t1+1-a-(2a-d). Thus, during the ready terminals are permitted to transmit a data packet and reduces to be d-a, and the ready terminals are inhibited to transmit and increases to be 1+d-a.

The virtual offered traffic on the forward channel, assume Poisson with average value G, consists of both new packet arrivals and rescheduled packets from both collisions and inhibited transmissions. With slotted non-persistent ISMA, the normalized slot length is set just slightly greater than (d-a)/2. It allows terminals to commence transmitting packets only at slot boundaries, thereby reducing collisions and resulting in higher throughput.

3.1.1 The throughput analysis

For the modified slotted np-ISMA, the busy period is found as

$$\overline{B}=\frac{1+d-a}{e^{-(d-a)G}} \tag{3.1}$$

The average idle period is found as

$$\overline{I}=\frac{d-a}{1-e^{-(d-a)G}} \tag{3.2}$$

The average successful packet transmission time in a cycle is found as

$$\overline{U}=\frac{\overline{B}}{1+(d-a)}P_{succ} \tag{3.3}$$

Where P_{succ} is the probability of a successful transmission period. We have

$$P_{succ}=\frac{Prob[single\ arrival\ within\ a\ slot]}{Prob[more\ arrivals\ within\ a\ slot]} \tag{3.4}$$

$$P_{succ}=\frac{(d-a)Ge^{-(d-a)G}}{1-e^{-(d-a)G}}$$

Putting all these together we get the average throughput is

$$S=\frac{\overline{U}}{\overline{B}+\overline{I}}=\frac{(d-a)Ge^{-(d-a)G}}{1+(d-a)-e^{-(d-a)G}} \tag{3.5}$$

3.1.2 The delay analysis

The packet delay is found using the quasi-static assumption of offered traffic applied to the slotted non-persistent ISMA protocol with timing advance. There are three components of packet delay:

1) When a data packet is successfully received, the normalized delay by the packet length is denoted by

$$D_s=1+(d-a) \tag{3.6}$$

2) When a data packet is unsuccessfully received due to a collision and retransmits until successfully received, the delay consists of the transmission time of the packet is $1+(d-a)$, the average propagation delay is $d/2$, the transmission time of the acknowledgement packet is T_a, and the average retransmission delay is T_c, that is

$$D_r=N_c\left(1+(d-a)+T_a+T_c\right) \tag{3.7}$$

which normalized by the packet length, where N_c is the average number of unsuccessful transmission attempts (collisions) a packet encounters before being successfully delivered.

3) When the forward channel is busy, the delay is

$$D_i=N_iT_r \tag{3.8}$$

where N_i is the average number of inhibited attempts before successful transmission packet, and T_r is the average retransmission wait time.

The expression for the average packet delay for slotted non-persistent ISMA with timing advance is

$$\overline{D}=1+(d-a)+N_c\left(1+(d-a)+T_a+T_c\right)+N_iT_r \tag{3.9}$$

The average number of collided attempts can be found as

$$N_c=\frac{(H-S)}{S} \tag{3.10}$$

The average number of inhibited attempts can be found as

$$N_i=\frac{(G-H)}{S} \tag{3.11}$$

where H is the rate of actual transmissions on the channel. For slotted non-persistent ISMA

$$H = H_S(d,G)$$

is modified as

$$H = \frac{(d-a)G^2 e^{-(d-a)G}}{1-e^{-(d-a)G}} \tag{3.12}$$

Thus, we are able to determine either the average packet delay time or the throughput as a function of the offered traffic.

3.2 The Low Earth Orbit (LEO) packet satellite communications:

The LEO packet satellite typically has the circular orbit about 200 to 2,000 kilometers above the earth's surface. The spot beam signal of satellite will make one cover zone on the earth's surface. Thus the cover zone diameter can be obtained as a function of satellite spot beamwidth.

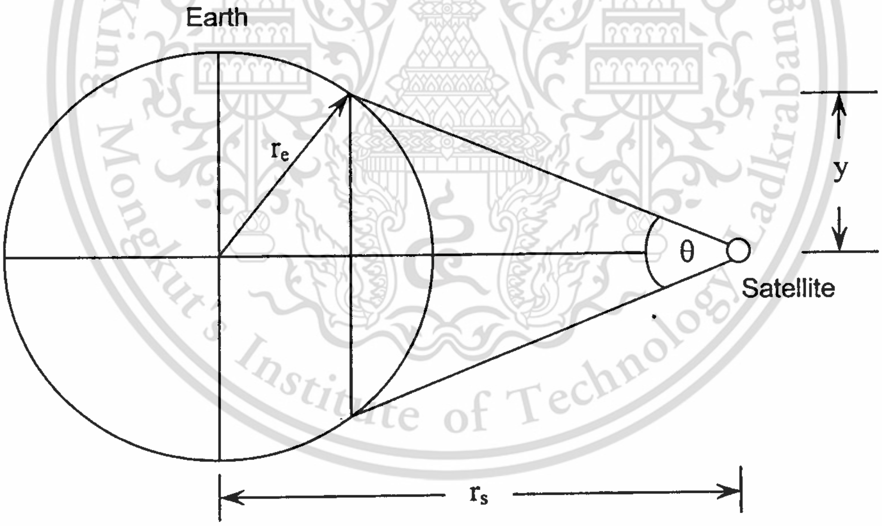

Figure 3.3 Geometric configuration for the calculation of the coverage zone diameter

A geometric approximation is adopted for the calculation of the cover zone diameter which is depending on the satellite antenna pattern. The pattern is frequently specified by its 3-dB beamwidth, the angle between the direction in which the radiated field falls to half the power in the direction of maximum field strength. However, a satellite antenna is used to provide coverage of a certain area, or zone on the earth's surface, and it is assumed to have circular contour of antenna gain in order to simply calculate.

Figure 3.3 shows the geometric configuration for the calculation of the coverage zone diameter. The beamwidth is denoted by θ in degree, the earth's radius is denoted by r_e which is about 6,370 kilometer, and the orbital radius of LEO satellite is denoted by r_s. The cover zone radius can be calculated as:

$$y = \frac{2r_s \tan\frac{\theta}{2} - \sqrt{4r_s^2 \tan^2\frac{\theta}{2} - 4\left(\tan^2\frac{\theta}{2}+1\right)\left(r_s^2 - r_e^2\right)}}{2\left(\tan^2\frac{\theta}{2}+1\right)} \qquad (3.13)$$

Chapter 4

Experiment results of modified slotted non persistent ISMA protocol on packet satellite communications

4.1 General simulation assumptions

4.1.1 System assumptions

1. The transmission method used here is the Frequency Division Duplex (FDD), with the difference frequency between uplink and downlink. The uplink is the radio channel to transmit data from terminals to base station. The downlink is the radio channel to broadcast signal and control message to the terminals.

2. The ready terminal is the terminal that has a packet ready for transmission at this instant (either a new packet just generated or a previously conflicted packet rescheduled for retransmission at this instant).

3. The packet transmission time is the time to successful transmits a packet from terminal to base station. A terminal may, at any one time, either be transmitting or receiving (but not both simultaneously). However, the delay incurred to switch from one mode to the other is negligible.

4. The time required to detect the carrier due to packet transmissions is negligible (zero detection time).

5. The time axis is slotted into segments whose durations are exactly equal to the transmission time of a single packet. All terminals are synchronized and are forced to start transmission their packets at the beginning of a slot.

6. The generation of a packet is independent of the past generation.

7. The probability of the packet does not change in each time slot of the simulation.

8. In a very small period, the probability in which more than two packets generated can be disregarded.

9. All packets are of constant length and are transmitted over an assumed noiseless channel (example, the errors in packet reception cause by random noise are

not consider to be a serious problem and are neglected in comparison with errors cause by overlap interference).

10. The system assumes noncapture (example, the overlap of any fraction of two packets results in destructive interference and both packets must be transmitted).

11. The propagation delay is assumed to be identical for all source destination pairs, because it is small compared to the packet transmission time.

12. If more than one terminal transmits their packets on the same time slot, the collision occurred and they must retransmit these packets till successful transmission.

13. When has no collision occur on the channel and a packet can be successful transmitted, the base station will send an acknowledge message to terminal to inform about that successful transmission packet.

14. The base station sends a busy signal to all other access terminals when base station is receiving packet from one access terminal. It is mean that base station will send the idle signal when it is not receiving any packets.

15. When each access terminal receives the idle signal, each access terminal must decide whether to transmit packets to the base station or not.

16. When each access terminal receives the busy signal, the packet transmission of each access terminal is inhibited.

4.1.2 Traffic model assumptions

1. We assume that our traffic source consists of an infinite number of terminals which collectively form an independent Poisson source with an aggregate mean packet generation rate of λ packet/s. This is an approximation to a large but finite population in which each terminal generates packets in frequently and each packet can be successfully transmitted in a time interval much less than the average time between successive packets generated by a given terminal. Each terminal in the infinite population is assumed to have at most one packet requiring transmission at any time (include any previously blocked packet).

2. We assume that each packet is of constant length requiring T seconds for transmission. We have $S = \lambda T$, with S is the average number of packets generated per

transmission time, example, it is the input rate normalized with respect to T. Under the steady state conditions, S can also be referred to as the channel throughput rate.

3. If we were able to perfectly schedule the packets into the available channel apace with absolutely no overlap or gaps between the packets, we could archive a maximum throughput equal to 1; therefore also refer to S as the channel utilization.

4. Because of interference problem inherent in random nature of the access modes, the achievable throughput will always be less than 1. The maximum achievable throughput for an access mode is called the capacity of the channel under that mode.

5. Since conflict can occur, some acknowledgment scheme is necessary to inform the transmitter of its success or failure. We assume a positive acknowledgement scheme: if within some specified delay (an appropriate time out period) after the transmission of a packet, a terminal does not receive acknowledgement, it knows it has conflicted. If it transmits immediately after received the idle signal from base station, and if all terminals behave likewise, then it will definitely be interfered with again (and forever!). The channel for acknowledgement is assumed to be separate from the channel we are studying; acknowledgements arrive reliably and at no cost.

6. The traffic offered to the channel from our collection of terminals consist not only of new packets but also of previously collided packets: this increases the mean offered traffic rate which we denote by G (packets per transmission time T) where $G \geq S$.

7. Each terminal delays the transmission of a previously collided packet by some random time whose mean is average transmission delay. The average transmission delay is large compared to transmission time T.

8. The interarrival times of the points process defined by the start times of all the packet plus retransmission are independent and exponentially distributed.

9. Without loss generality, we choose $T = 1$. This is equivalent to expressing time in units of T.

4.13 The Basic configuration of computer simulation

The Basic configuration of computer simulation is shown in Figure 4.0. In our computer simulations, it is assumed that propagation loss and shadowing are constant.

Until the number of successfully transmitted packet is equal to the required number, the computer simulation is continued.

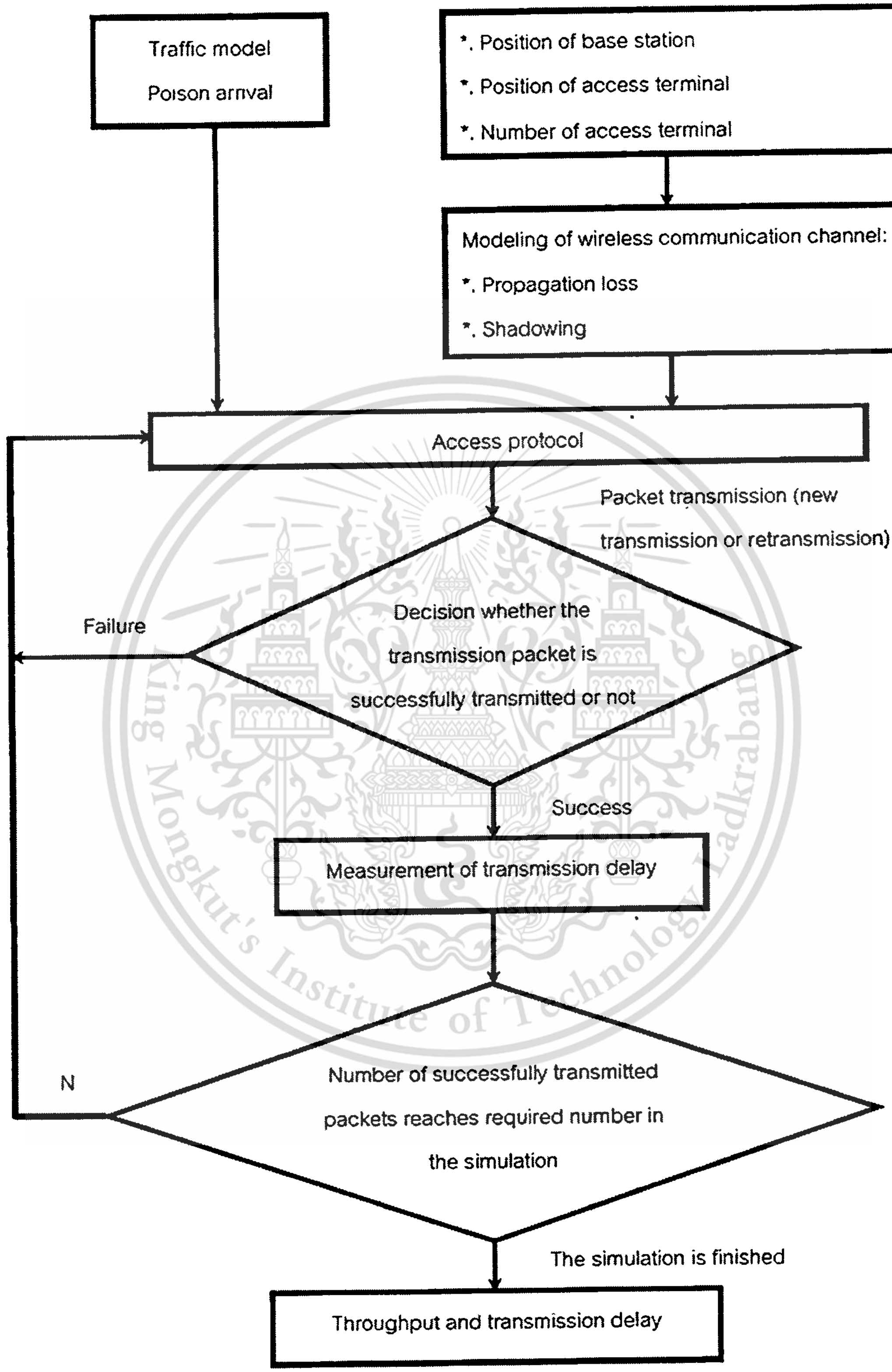

Figure 4.1 Basic configuration of computer simulation

4.2 Experiment simulation results of the slotted non persistent ISMA protocol

In this part, we will evaluate the performance of the slotted non persistent ISMA protocol by the results of simulations. By the way to change the values of tree parameters: cover zone radius, packet length and symbol rate, through simulations, we will analyze how the slotted non persistent ISMA protocol works.

We will evaluate the performance of this protocol by four simulation elements: throughput, average packet delay, number of collided attempt time and number of inhibited attempt time.

The protocol has a good performance if it has high value of throughput.

The protocol has a good performance if it has small value of average packet delay.

The protocol has a good performance if it has small value of number of collided attempt time.

The protocol has a good performance if it has small value of number of inhibited attempt time.

4.2.1 Simulation results when varied the value of cover zone radius

Table 4.1 shows the conditions of the simulation with the values of cover zone radius (r) are varied from 100km to 1,000km.

Table 4.1 Simulation condition assumptions of the slotted np-ISMA protocol with the varying values of cover zone radius (r)

Symbol rate	Srate	256	ksymbol/second
Length of the packet	Mplen	128	symbol
Inhibited time (normalized)	d	0.00136	-
Cover zone radius	r	100, 400, 700, 1,000 km	
High of the base station	-	100	km
Number of terminal	Mnum	300	-

1. Relation between throughput and offered traffic of the slotted np-ISMA protocol when varying the value of cover zone radius (r):

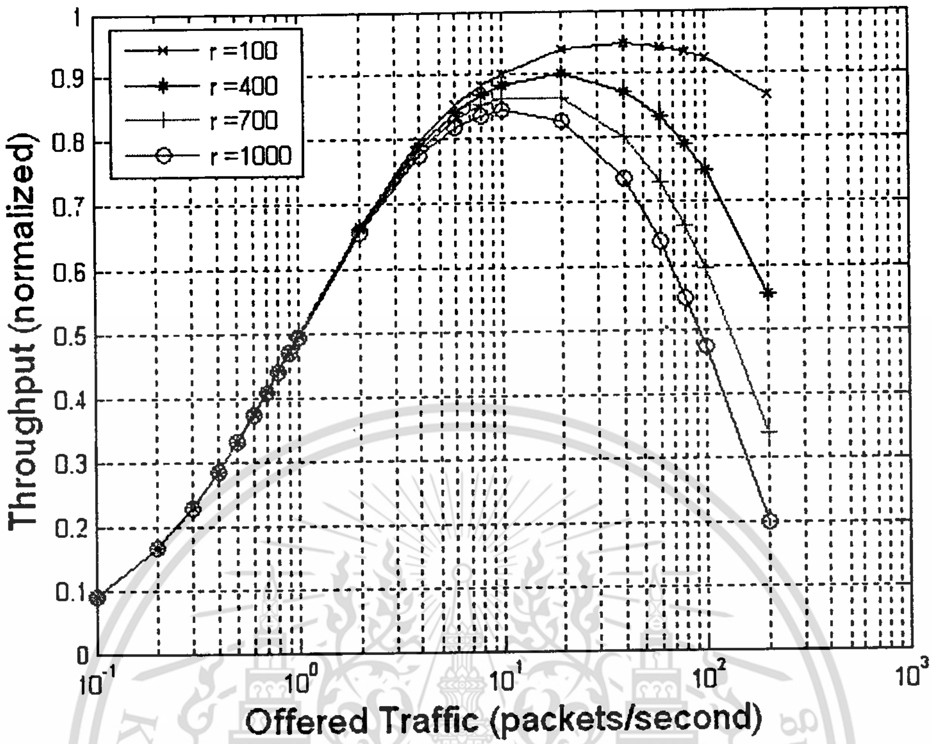

Figure 4.2 Throughput of slotted np-ISMA protocol with cover zone radius (r) = 100, 400, 700 and 1.000 km

In figure 4.2, with four values of cover zone radius: 100, 400, 700 and 1,000km, when the offered traffic G = 200 packet/second, the throughputs received are 0.8654, 0.5551, 0.3387 and 0.1995, and the maximum throughput received are 0.9487, 0.9001, 0.8637 and 0.8451. It is mean that the throughput decreased when the cover zone radius increased, and the slotted np-ISMA protocol has better performance when the cover zone radius decreased.

2. Relation between packet delay and offered traffic of the slotted np-ISMA protocol when varying the value of cover zone radius (r):

In figure 4.3, with four values of cover zone radius: 100, 400, 700 and 1,000km, when the offered traffic G = 200 packet/second, the packet delays received are 0.1158, 0.181697, 0.2995 and 0.5115. It is mean that the packet delays increased when the cover zone radius increased, and the slotted np-ISMA protocol has better performance when the cover zone radius decreased.

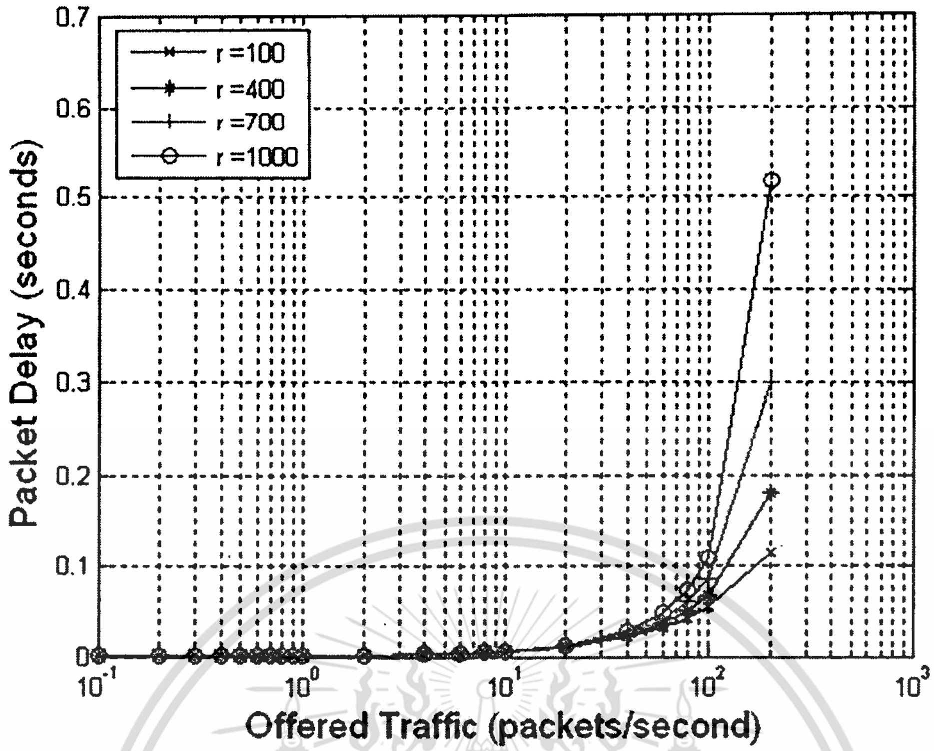

Figure 4.3 Packet delay of slotted np-ISMA protocol with cover zone radius (r) = 100, 400, 700 and 1.000 km

3. Relation between the numbers of collided attempt time and offered traffic of the slotted np-ISMA protocol when varying the value of cover zone radius (r):

In figure 4.4, with four values of cover zone radius: 100, 400, 700 and 1,000km, when the offered traffic G = 200 packet/second, the numbers of collided attempt time received are 230.0940, 359.2784, 589.3956 and 1001.3690. It is mean that the collided attempt time increased when the cover zone radius increased, and the slotted np-ISMA protocol has better performance when the cover zone radius decreased.

4. Relation between the numbers of inhibited attempt time and offered traffic of the slotted np-ISMA protocol when varying the value of cover zone radius (r):

In figure 4.5, with four values of cover zone radius: 100, 400, 700 and 1,000km, when the offered traffic G = 200 packet/second, the numbers of inhibited attempt time received are 29.9521, 158.6518, 388.1911 and 799.5231. It is mean that the inhibited attempt time increased when the cover zone radius increased, and the slotted np-ISMA protocol has better performance when the cover zone radius decreased.

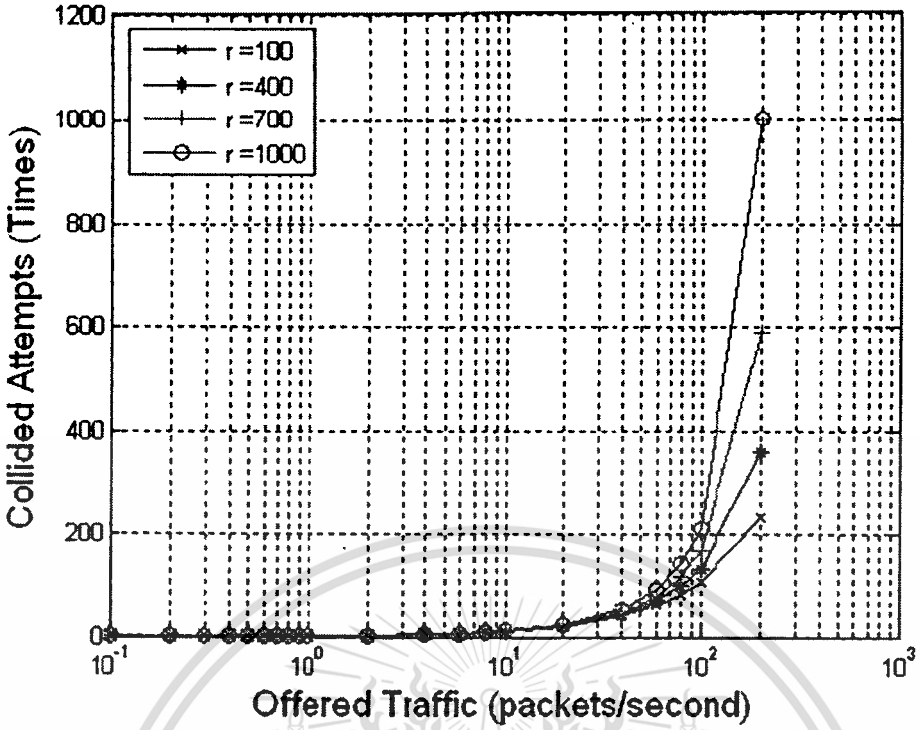

Figure 4.4 Collided attempts of slotted np-ISMA protocol with cover zone radius (r) = 100, 400, 700 and 1.000 km

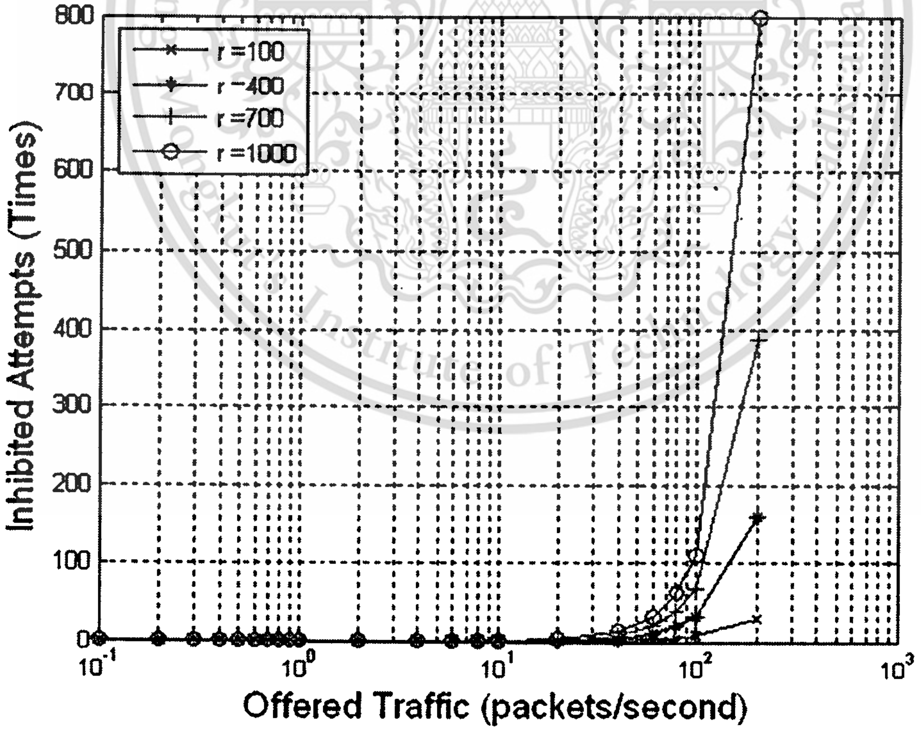

Figure 4.5 Inhibited attempts of slotted np-ISMA protocol with cover zone radius (r) = 100, 400, 700 and 1.000 km

Summary of the slotted np-ISMA protocol's simulation results is showed in the table 4.2, when the value of cover zone radius varies from 100km to 1000km.

Table 4.2 Simulation results of the slotted np-ISMA protocol with the varying values of cover zone radius (r), when the offered traffic (G) = 200 packet/second

Simulation Element	Cover zone Radius (r) [km]			
	100	400	700	1,000
Max Throughput	0.9487	0.9001	0.8637	0.8451
Throughput	0.8654	0.5551	0.3387	0.1995
Packet Delay	0.1158	0.1816	0.2995	0.5115
Collided Attempt	230.0940	359.2784	589.3956	1001.3690
Inhibited Attempt	29.9521	158.6518	388.1911	799.5231

4.2.2 Simulation results when varied the value of length of the packet

Table 4.3 shows the conditions of the simulation with the values of length of the packet (Mplen) are varied from 128 to 1,024 symbol.

Table 4.3 Simulation condition assumptions of the slotted np-ISMA protocol with the varying values of length of the packet (Mplen)

Symbol rate	Srate	256	ksymbol/second
Length of the packet	Mplen	128, 256, 512, 1,024 symbol	
Inhibited time (normalized)	d	0.00136	-
Cover zone radius	r	100	km
High of the base station	-	100	km
Number of terminal	Mnum	300	-

1. Relation between throughput and offered traffic of the slotted np-ISMA protocol when varying the value of length of the packet (Mplen):

In figure 4.6, with four values of length of the packet: 128, 256, 512 and 1,024 symbol, when the offered traffic G = 200 packet/second, the throughputs received are 0.8652, 0.9285, 0.9615 and 0.9781, and the maximum throughput received are 0.9486, 0.9633, 0.9741 and 0.9816. It is mean that the throughput increased when the length of the packet increased, and the slotted np-ISMA protocol has better performance when the length of the packet increased.

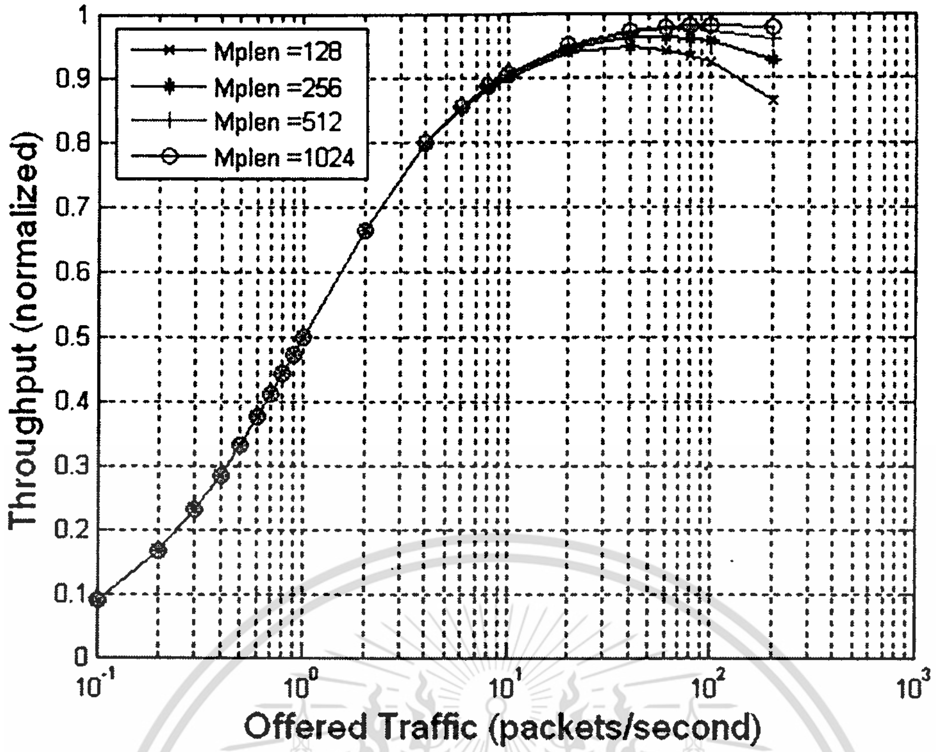

Figure 4.6 Throughput of slotted np-ISMA protocol with packet length (Mplen) = 128, 256, 512 and 1.024 symbol

2. Relation between packet delay and offered traffic of the slotted np-ISMA protocol when varying the value of length of the packet (Mplen):

In figure 4.7, with four values of length of the packet: 128, 256, 512 and 1,024 symbol, when the offered traffic G = 200 packet/second, the packet delays received are 0.1153, 0.2148, 0.4149 and 0.8170. It is mean that the packet delays increased when the length of the packet increased, and the slotted np-ISMA protocol has better performance when the length of the packet decreased.

3. Relation between the numbers of collided attempt time and offered traffic of the slotted np-ISMA protocol when varying the value of length of the packet (Mplen):

In figure 4.8, with four values of length of the packet: 128, 256, 512 and 1,024 symbol, when the offered traffic G = 200 packet/second, the numbers of collided attempt time received are 230.1449, 214.3787, 206.9998 and 203.4648. It is mean that the the collided attempt times decreased when the length of the packet increased, and the slotted np-ISMA protocol has better performance when the length of the packet increased.

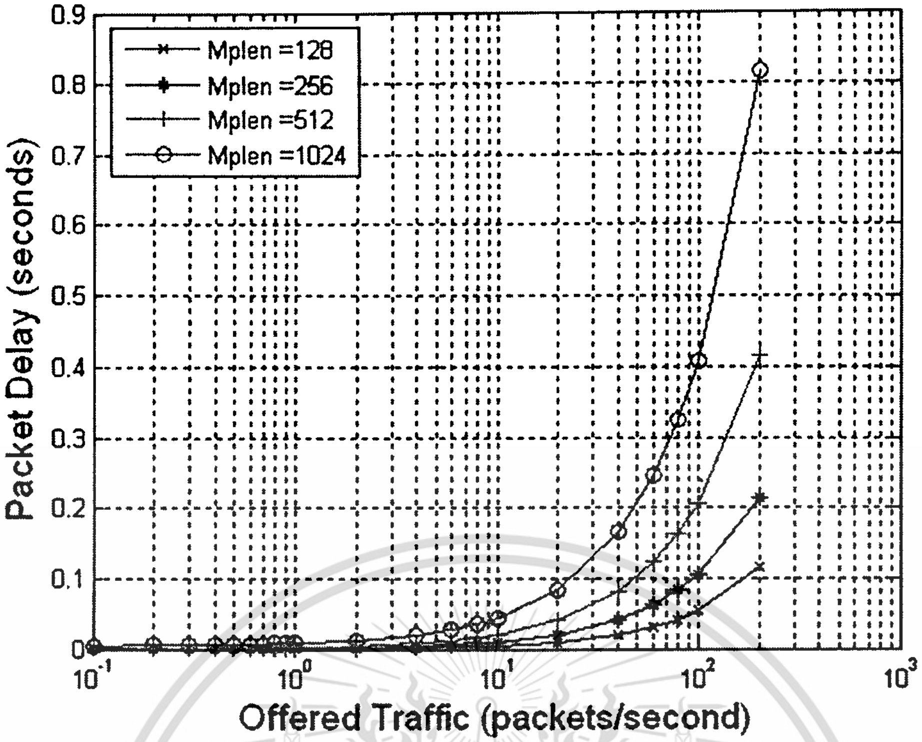

Figure 4.7 Packet delay of slotted np-ISMA protocol with packet length (Mplen) = 128, 256, 512 and 1.024 symbol

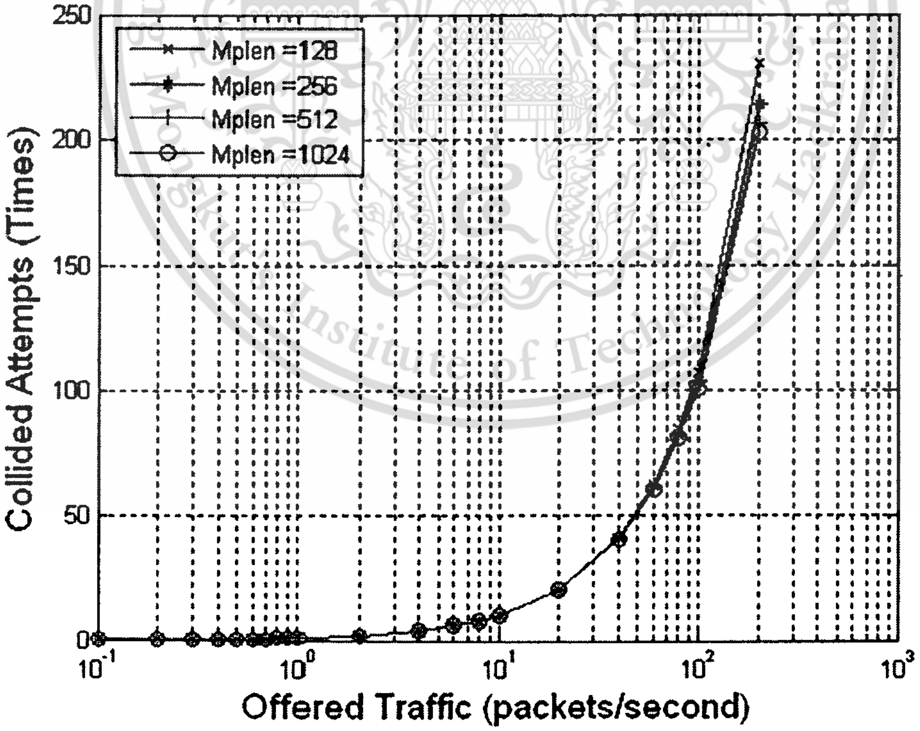

Figure 4.8 Collided attempts of slotted np-ISMA protocol with packet length (Mplen) = 128, 256, 512 and 1.024 symbol

4. Relation between the numbers of inhibited attempt time and offered traffic of the slotted np-ISMA protocol when varying the value of length of the packet (Mplen):

In figure 4.9, with four values of length of the packet: 128, 256, 512 and 1,024 symbol, when the offered traffic G = 200 packet/second, the numbers of inhibited attempt time received are 30.0027, 14.3091, 6.9655 and 3.4477. It is mean that the inhibited attempt times decreased when the length of the packet increased, and the slotted np-ISMA protocol has better performance when the length of the packet increased.

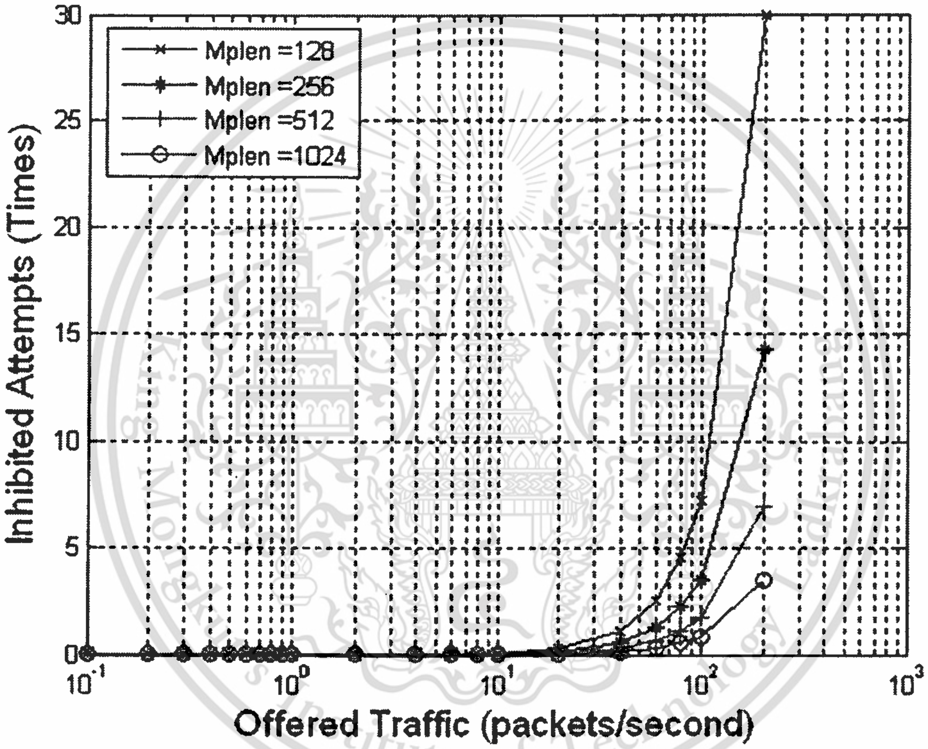

Figure 4.9 Inhibited attempts of slotted np-ISMA protocol with packet length (Mplen) = 128, 256, 512 and 1.024 symbol

Summary of the slotted np-ISMA protocol's simulation results is showed in the table 4.4, when the values of length of the packet (Mplen) are varied from 128 to 1,024 symbol.

Table 4.4 Simulation results of the slotted np-ISMA protocol with the varying values of packet length(Mplen), when the offered traffic (G) = 200 packet/second

Simulation Element	Length Of The Packet (Mplen) [symbol]			
	128	256	512	1,024
Max Throughput	0.9486	0.9633	0.9741	0.9816
Throughput	0.8652	0.9285	0.9615	0.9781
Packet Delay	0.1153	0.2148	0.4149	0.8170
Collided Attempt	230.1449	214.3787	206.9998	203.4648
Inhibited Attempt	30.0027	14.3091	6.9655	3.4477

4.2.3 Simulation results when varied the value of symbol rate

Table 4.5 shows the conditions of the simulation with the values of symbol rate (Srate) are varied from 256 to 2,048ksymbol/second.

Table 4.5 Simulation condition assumptions of the slotted np-ISMA protocol with the varying values of symbol rate (Srate)

Symbol rate	Srate	256, 512, 1,024, 2,048 ksymbol/second	
Length of the packet	Mplen	128	Symbol
Inhibited time (normalized)	d	0.00136	-
Cover zone radius	r	100	km
High of the base station	-	100	km
Number of terminal	Mnum	300	-

1. Relation between throughput and offered traffic of the slotted np-ISMA protocol when varying the value of symbol rate (Srate):

In figure 4.10, with four values of symbol rate: 256, 512, 1,024 and 2,048 ksymbol/second, when the offered traffic G = 200 packet/second, the throughputs received are 0.8653, 0.7481, 0.5491 and 0.2755, and the maximum throughput received are 0.9487, 0.9255, 0.8992 and 0.8562. It is mean that the throughput decreased when the symbol rate increased, and the slotted np-ISMA protocol has better performance when the symbol rate decreased.

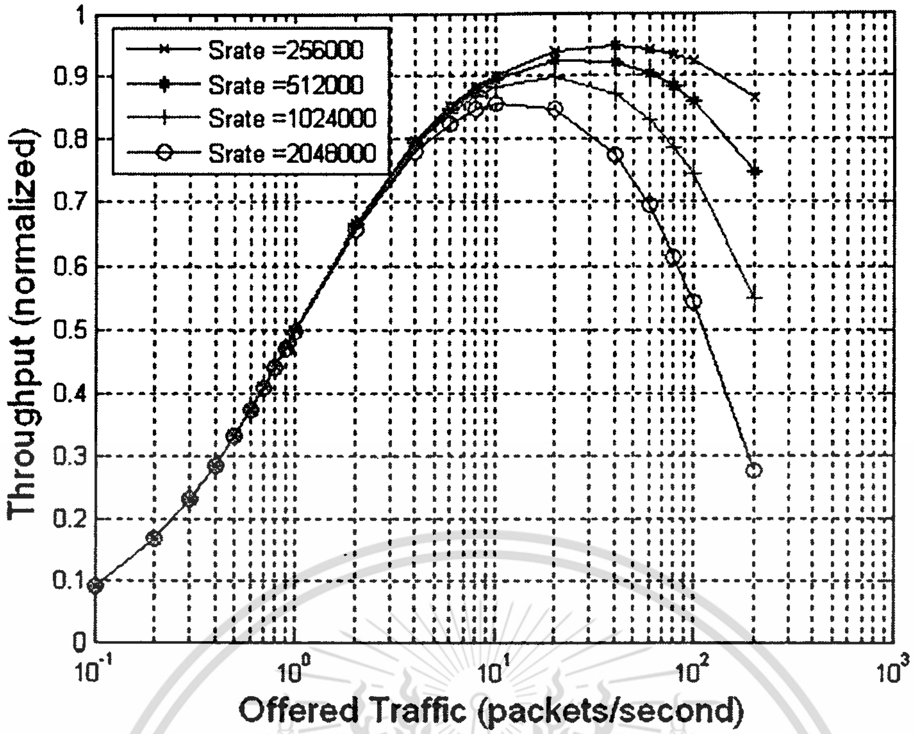

Figure 4.10 Throughput of slotted np-ISMA protocol with symbol rate (Srate) = 256, 512, 1.024 and 2.048 ksymbol/s

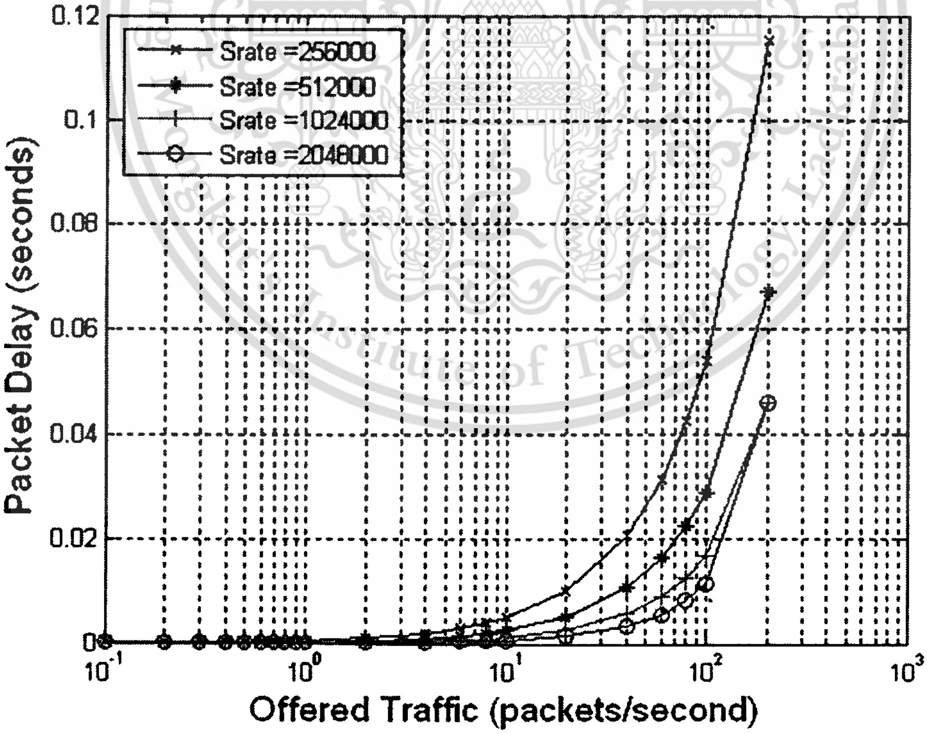

Figure 4.11 Packet delay of slotted np-ISMA protocol with symbol rate (Srate) = 256, 512, 1.024 and 2.048 ksymbol/s

2. Relation between packet delay and offered traffic of the slotted np-ISMA protocol when varying the value of symbol rate (Srate):

In figure 4.11, with four values of symbol rate: 256, 512, 1,024 and 2,048 ksymbol/second, when the offered traffic G = 200 packet/second, the packet delays received are 0.1153, 0.0668, 0.0457 and 0.0460. It is mean that the packet delays decreased when symbol rate increased, and the slotted np-ISMA protocol has better performance when symbol rate increased.

3. Relation between the numbers of collided attempt time and offered traffic of the slotted np-ISMA protocol when varying the value of symbol rate (Srate):

In figure 4.12, with four values of symbol rate: 256, 512, 1,024 and 2,048 ksymbol/second, when the offered traffic G = 200 packet/second, the numbers of collided attempt time received are 230.1274, 266.3397, 363.2177 and 724.7623. It is mean that the the collided attempt times increased when symbol rate increased, and the slotted np-ISMA protocol has better performance when symbol rate decreased.

4. Relation between the numbers of inhibited attempt time and offered traffic of the slotted np-ISMA protocol when varying the value of symbol rate (Srate):

In figure 4.13, with four values of symbol rate: 256, 512, 1,024 and 2,048 ksymbol/second, when the offered traffic G = 200 packet/second, the numbers of inhibited attempt time received are 29.9853, 66.0438, 162.5787 and 523.3093. It is mean that the the inhibited attempt times increased when symbol rate increased, and the slotted np-ISMA protocol has better performance when symbol rate decreased.

Summary of the slotted np-ISMA protocol's simulation results is showed in the table 4.6, when the values of symbol rate (Srate) are varied from 256 to 2,048 ksymbol/second.

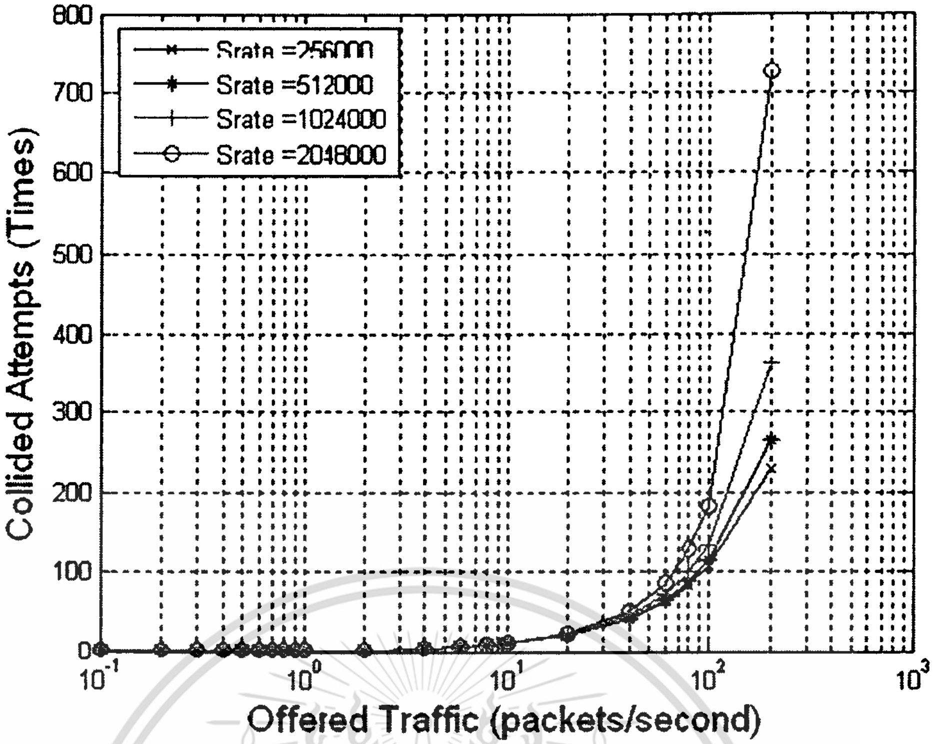

Figure 4.12 Collided attempts of slotted np-ISMA protocol with symbol rate (Srate) = 256, 512, 1.024 and 2.048 ksymbol/s

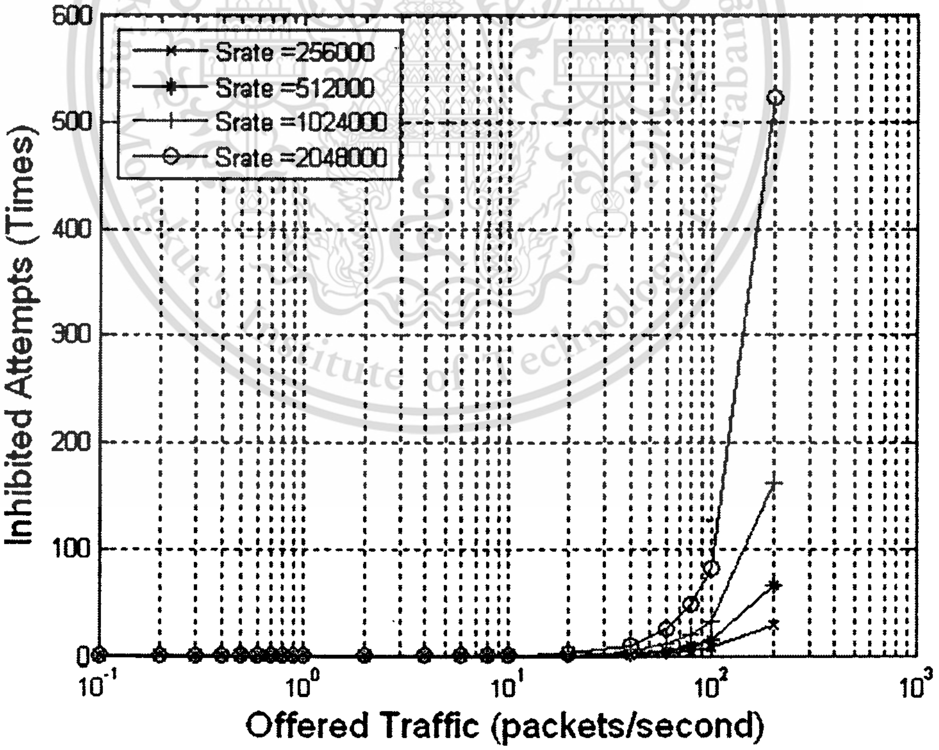

Figure 4.13 Inhibited attempts of slotted np-ISMA protocol with symbol rate (Srate) = 256, 512, 1.024 and 2.048 ksymbol/s

Table 4.6 Simulation results of the slotted np-ISMA protocol with the varying values of symbol rate (Srate), when the offered traffic (G) = 200 packet/second

Simulation Element	Symbol Rate (Srate) [ksymbol/second]			
	256	512	1,024	2,048
Max Throughput	0.9487	0.9255	0.8992	0.8562
Throughput	0.8653	0.7481	0.5491	0.2755
Packet Delay	0.1153	0.0668	0.0457	0.0460
Collided Attempt	230.1274	266.3397	363.2177	724.7623
Inhibited Attempt	29.9853	66.0438	162.5787	523.3093

4.2.4 Conclusions

Through all of the simulation results above, we can conclude that the performance of the slotted non persistent ISMA protocol will be increased when the service are radius is decreased, the length of the packet is decreased and the symbol rate is decreased.

4.3 Experiment simulation results of the modified slotted non persistent ISMA protocol

In this part, we will evaluate the performance of the modified slotted non persistent ISMA protocol with three value of timing advance factors, (a) = 30%, 60% and 90% of inhibited time (d). The comparisons with the original slotted non persistent ISMA protocol (when a = 0%) will be showed by the results of simulations. By the way to change the values of tree parameters: cover zone radius, packet length and symbol rate, through simulations, we will analyze how the slotted non persistent ISMA protocol works.

We will evaluate the performance of this protocol by four simulation elements: throughput, average packet delay, number of collided attempt time and number of inhibited attempt time.

The protocol has a good performance if it has high value of throughput.

The protocol has a good performance if it has small value of average packet delay.

The protocol has a good performance if it has small value of number of collided attempt time.

The protocol has a good performance if it has small value of number of inhibited attempt time.

4.3.1 Simulation results when varied the value of cover zone radius

Table 4.7 shows the conditions of the simulation with the values of cover zone radius (r) are varied from 100 to 1,000km.

Table 4.7 Simulation condition assumptions of the modified slotted np-ISMA protocol with the varying values of cover zone radius (r)

Symbol rate	Srate	256	ksymbol/second
Length of the packet	Mplen	128	symbol
Inhibited time (normalized)	D	0.0013	-
Cover zone radius	R	100, 400, 700, 1,000 km	
High of the base station	-	100	km
Number of terminal	Mnum	300	-
Timing advance (% of Inhibited time)	A	0%, 30%, 60%, 90%	

1. Relation between throughput and offered traffic of the modified slotted np-ISMA protocol when varying the value of cover zone radius (r):

In figure 4.14, with cover zone radius r = 100km and offered traffic G = 200 packet/second, when the values of timing advance increased from 0% to 30%, 30% to 60% and 60% to 90%, the throughputs of modified slotted np-ISMA protocol increased 4.33%, 4.29% and 4.23%, respectively. The maximum throughputs of modified slotted np-ISMA protocol increased 0.84%, 1.12% and 1.64% respectively. With the cover zone radius r = 100km and 1,000km, when the values of timing advance increased from 0% to 90%, the throughputs of modified slotted np-ISMA protocol increased 13.41% and 341.92%, respectively. The maximum throughputs of modified slotted np-ISMA protocol

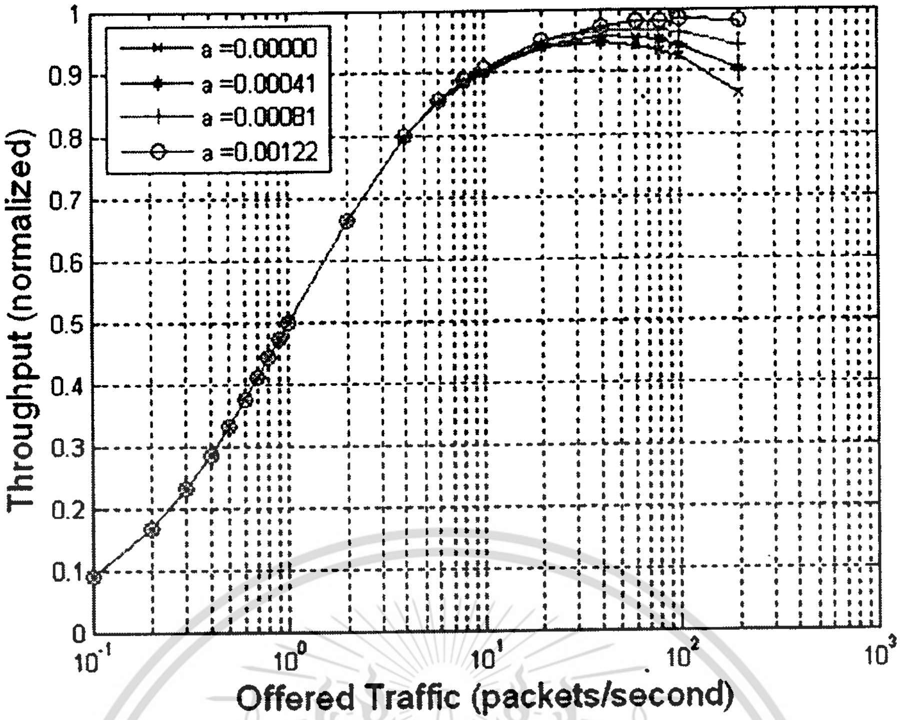

Figure 4.14a Throughput of modified slotted np-ISMA protocol with service area radius (r) = 100km

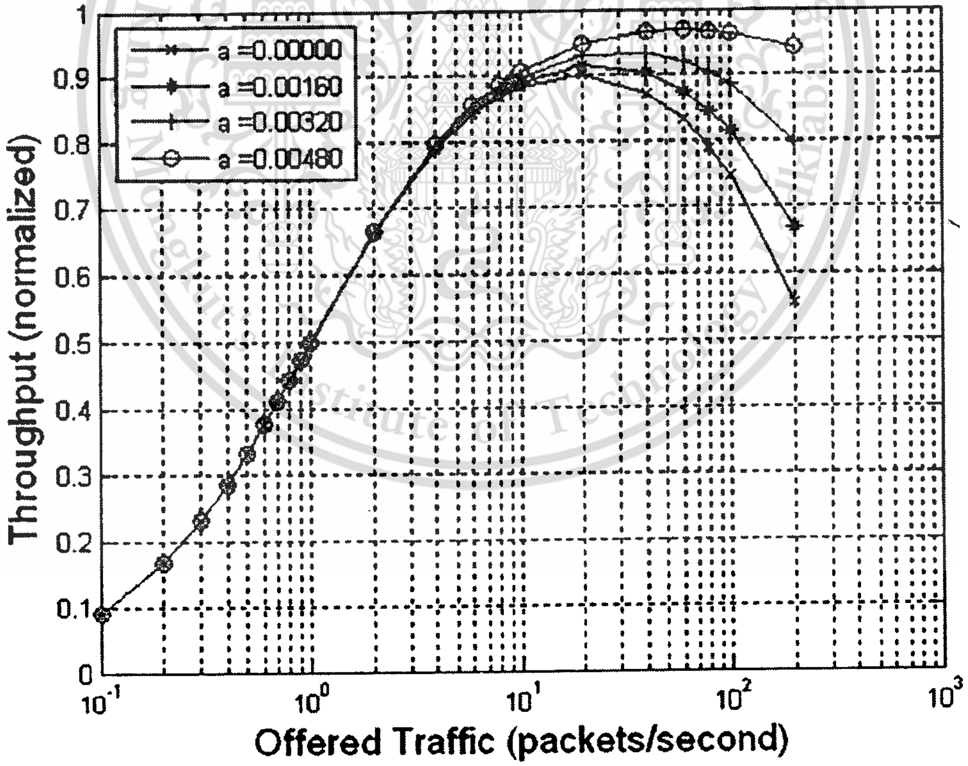

Figure 4.14b Throughput of modified slotted np-ISMA protocol with service area radius (r) = 400km

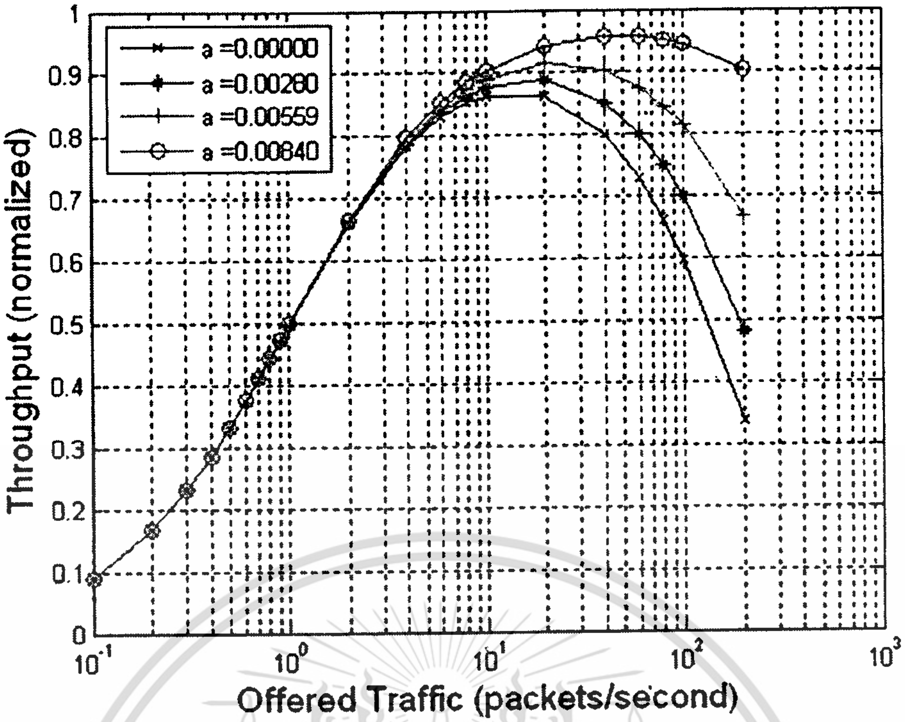

Figure 4.14c Throughput of modified slotted np-ISMA protocol with service area radius (r) = 700km

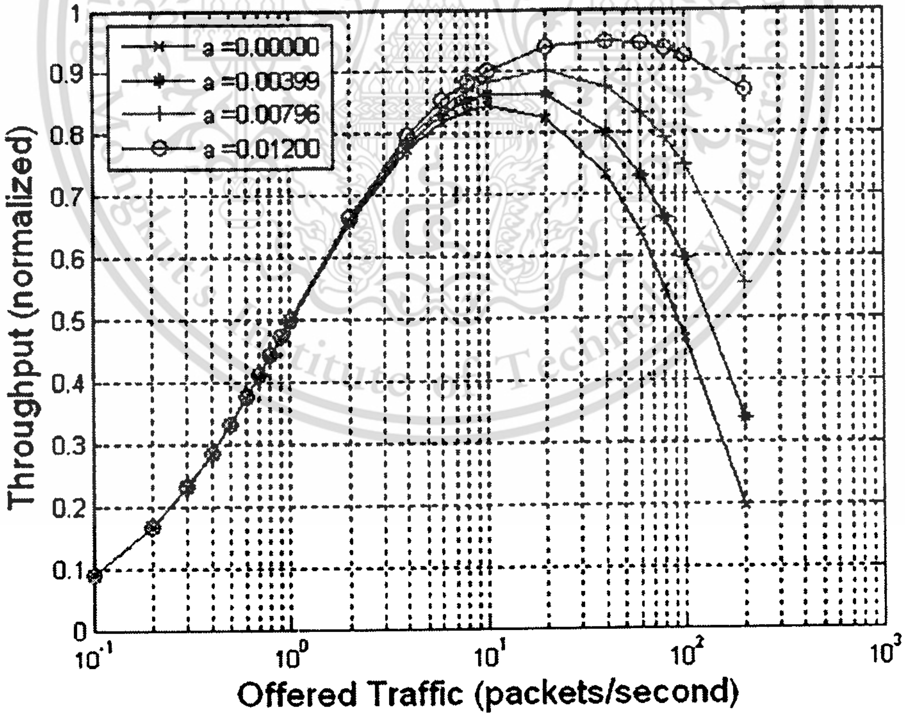

Figure 4.14d Throughput of modified slotted np-ISMA protocol with service area radius (r) = 1,000km

Table 4.8 Throughput of the modified slotted np-ISMA protocol with the varying values of cover zone radius (r), when the offered traffic (G) = 200 packet/s

Cover zone Radius (r) [km]	Throughput (normalized)			
	ISMA	ISMA +30%	ISMA +60%	ISMA +90%
100	0.8654	0.9029	0.9416	0.9814
400	0.5552	0.6682	0.7967	0.9425
700	0.3379	0.4810	0.6682	0.9045
1,000	0.1963	0.3383	0.5569	0.867659

Table 4.9 Maximum throughput of the modified slotted np-ISMA protocol with the varying values of cover zone radius (r)

Cover zone Radius (r) [km]	Maximum Throughput (normalized)			
	ISMA	ISMA +30%	ISMA +60%	ISMA +90%
100	0.9487	0.9567	0.9673	0.9833
400	0.9001	0.9156	0.9335	0.9676
700	0.8636	0.8887	0.9156	0.9570
1,000	0.8446	0.8636	0.9004	0.9492

2. Relation between packet delay and offered traffic of the modified slotted np-ISMA protocol when varying the value of cover zone radius (r):

In figure 4.15, with cover zone radius r = 100km and offered traffic G = 200 packet/second, when the values of timing advance increased from 0% to 30%, 30% to 60% and 60% to 90%, the packet delays of modified slotted np-ISMA protocol decreased 4.21%, 4.17% and 4.12%, respectively. With the cover zone radius r = 100km and 1,000km, when the values of timing advance increased from 0% to 90%, the packet delays of modified slotted np-ISMA protocol decreased 11.99% and 77.72%, respectively. The summary of these simulation results is showed in table 4.10.

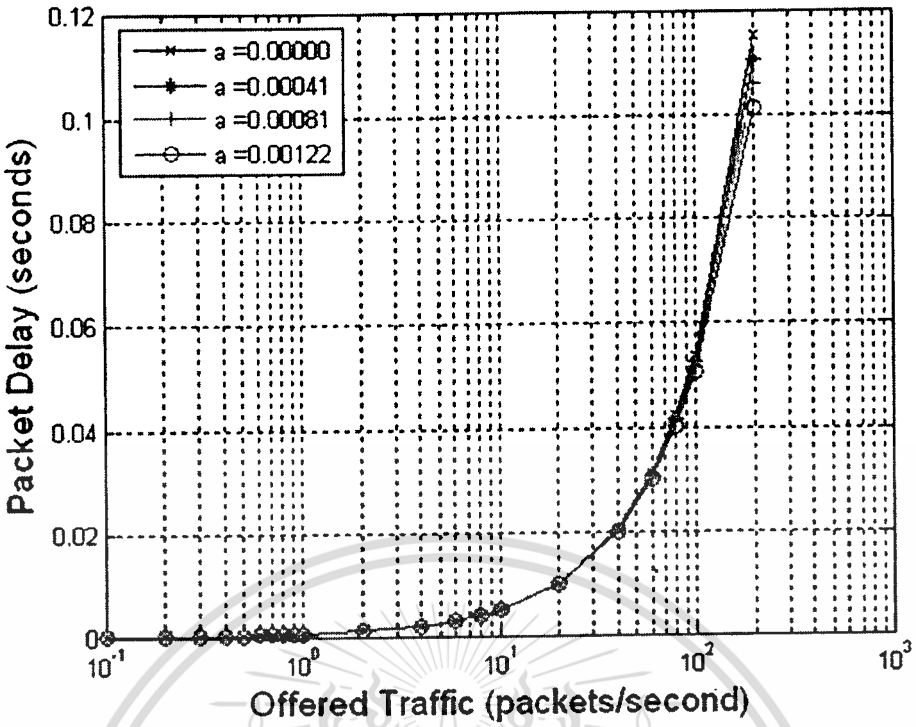

Figure 4.15a Packet delay of modified slotted np-ISMA protocol with service area radius (r) = 100km

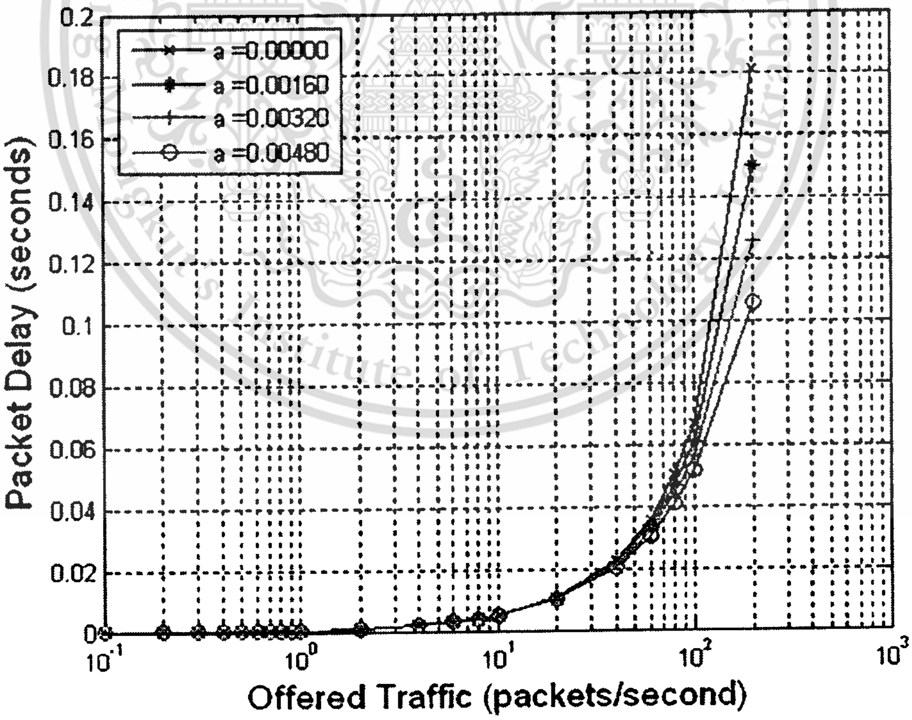

Figure 4.15b Packet delay of modified slotted np-ISMA protocol with service area radius (r) = 400km

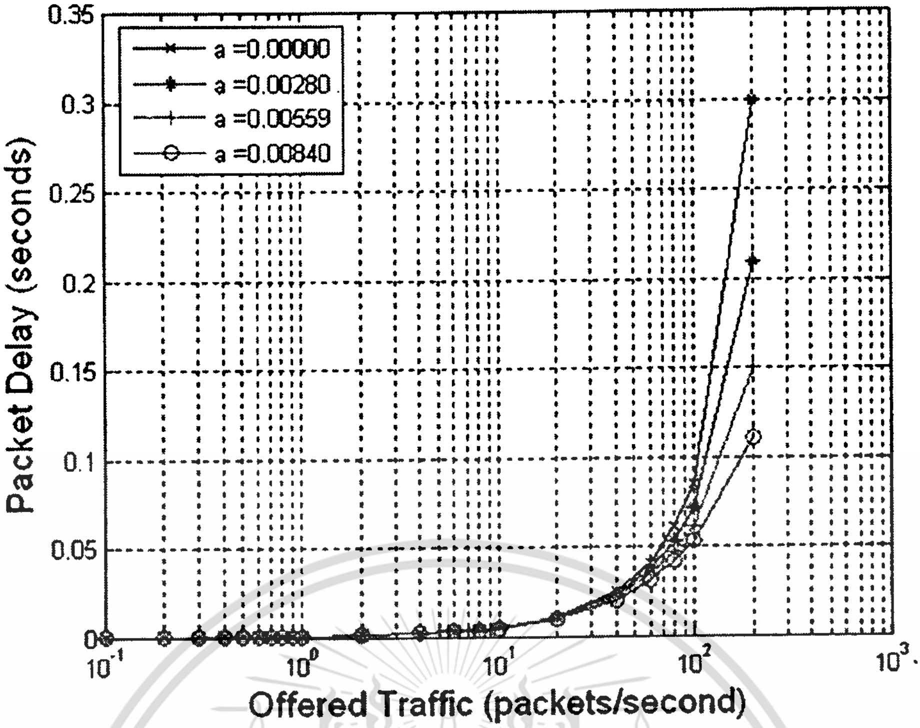

Figure 4.15c Packet delay of modified slotted np-ISMA protocol with service area radius (r) = 700km

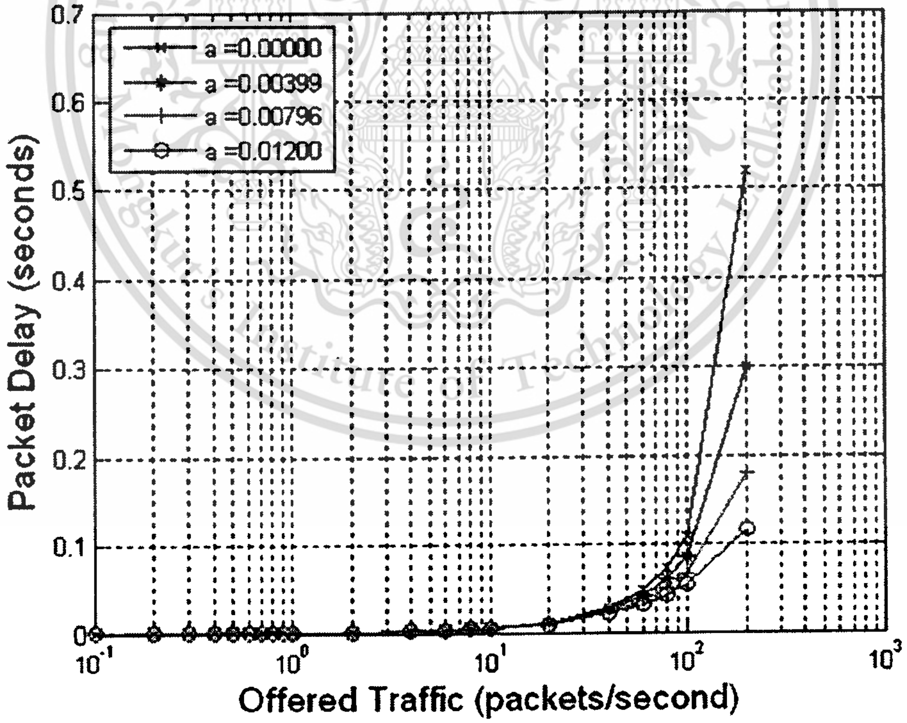

Figure 4.15d Packet delay of modified slotted np-ISMA protocol with service area radius (r) = 1,000km

Table 4.10 Packet delay of the modified slotted np-ISMA protocol with the varying values of cover zone radius (r), when the offered traffic (G) = 200 packet/s

Cover zone Radius (r) [km]	Packet Delay (normalized)			
	ISMA	ISMA +30%	ISMA +60%	ISMA +90%
100	0.1153	0.1104	0.1058	0.1015
400	0.1811	0.1502	0.1256	0.1059
700	0.2997	0.2098	0.1504	0.1107
1,000	0.5194	0.2999	0.1813	0.1157

3. Relation between collided attempt times and offered traffic of the modified slotted np-ISMA protocol when varying the value of cover zone radius (r):

In figure 4.16, with cover zone radius r = 100km and offered traffic G = 200 packet/second, when the values of timing advance increased from 0% to 30%, 30% to 60% and 60% to 90%, the collided attempt times of modified slotted np-ISMA protocol decreased 4.17%, 4.13% and 4.08%, respectively. With the cover zone radius r = 100km and 1000km, when the values of timing advance increased from 0% to 90%, the collided attempt times of modified slotted np-ISMA protocol decreased 11.87% and 77.45%, respectively. The summary of these simulation results is showed in table 4.11.

Table 4.11 Collided attempt of the modified slotted np-ISMA protocol with the varying values of cover zone radius (r), when the offered traffic (G) = 200 packet/s

Cover zone Radius (r) [km]	Collided Attempt (times)			
	ISMA	ISMA +30%	ISMA +60%	ISMA +90%
100	230.0940	220.4937	211.3874	202.7719
400	359.2295	298.3108	250.0048	211.1793
700	590.7981	414.7736	298.2911	220.0963
1,000	1017.6420	590.0717	358.1077	229.5054

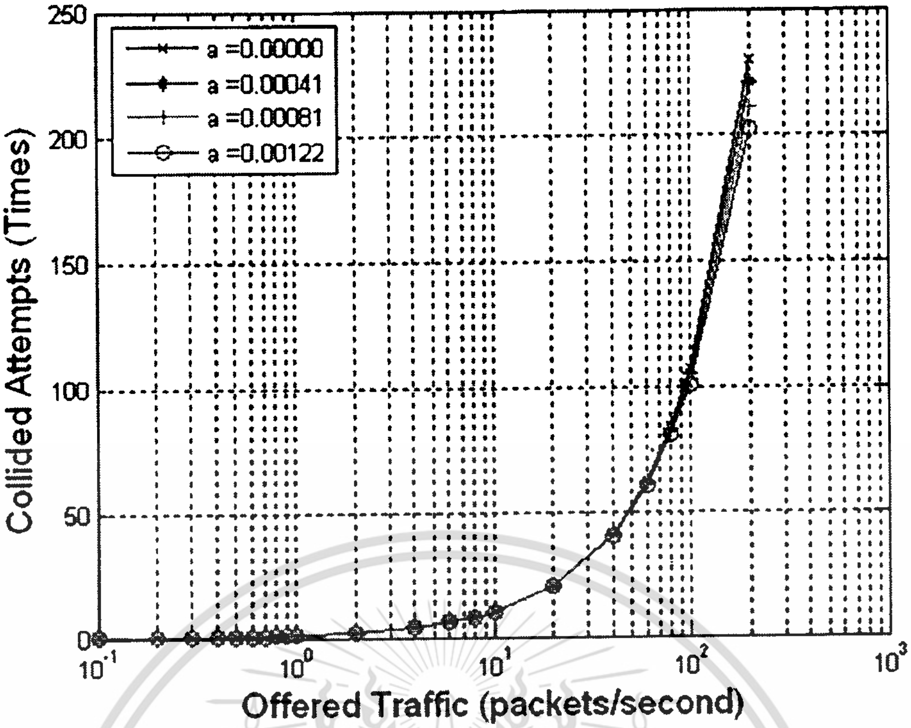

Figure 4.16a Collided attempts of modified slotted np-ISMA protocol with service area radius (r) = 100km

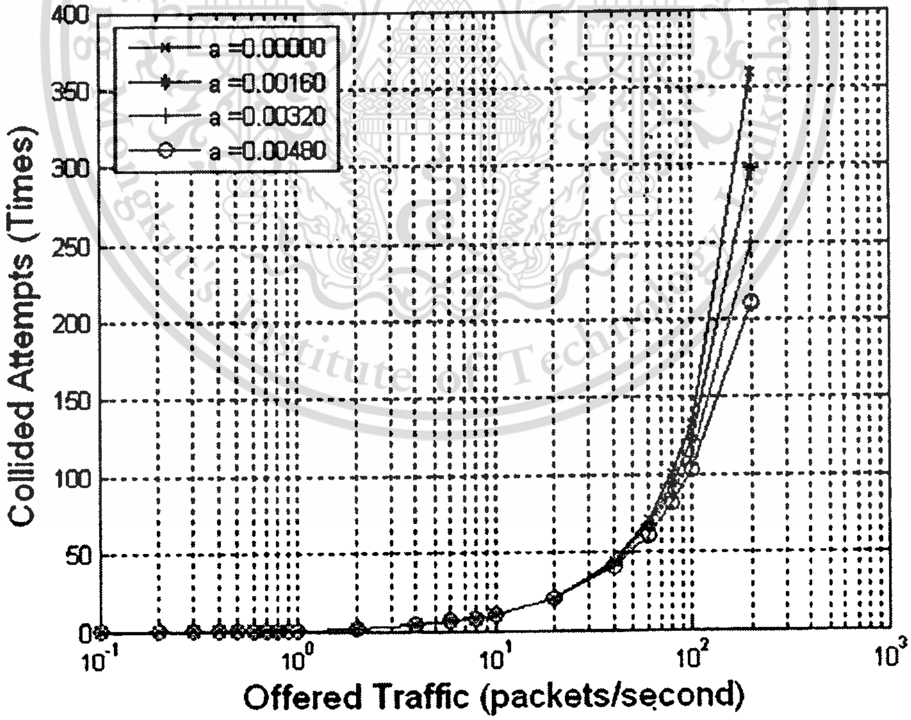

Figure 4.16b Collided attempts of modified slotted np-ISMA protocol with service area radius (r) = 400km

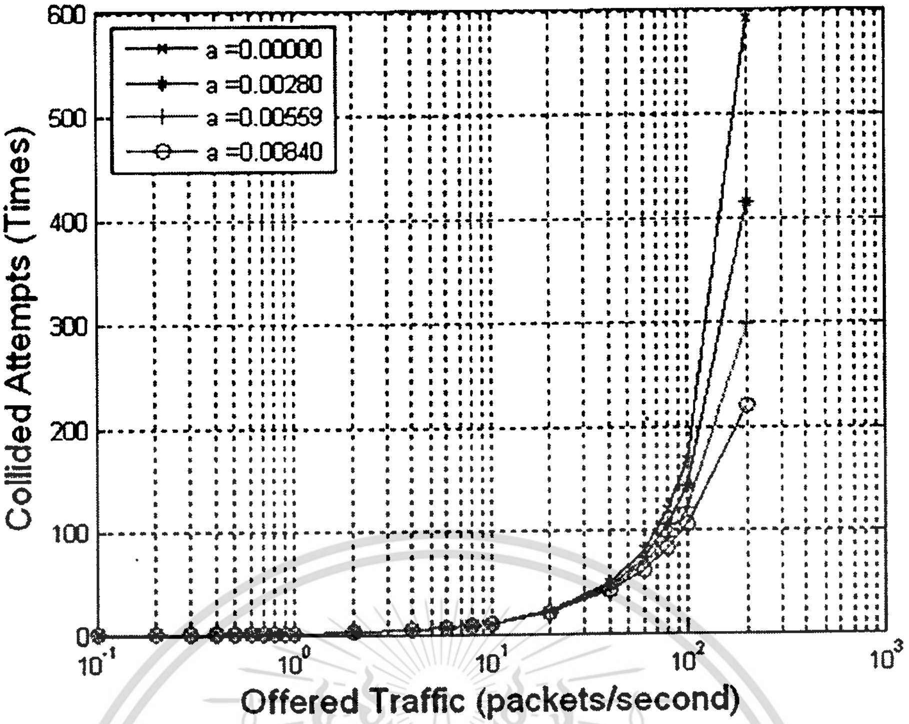

Figure 4.16c Collided attempts of modified slotted np-ISMA protocol with service area radius (r) = 700km

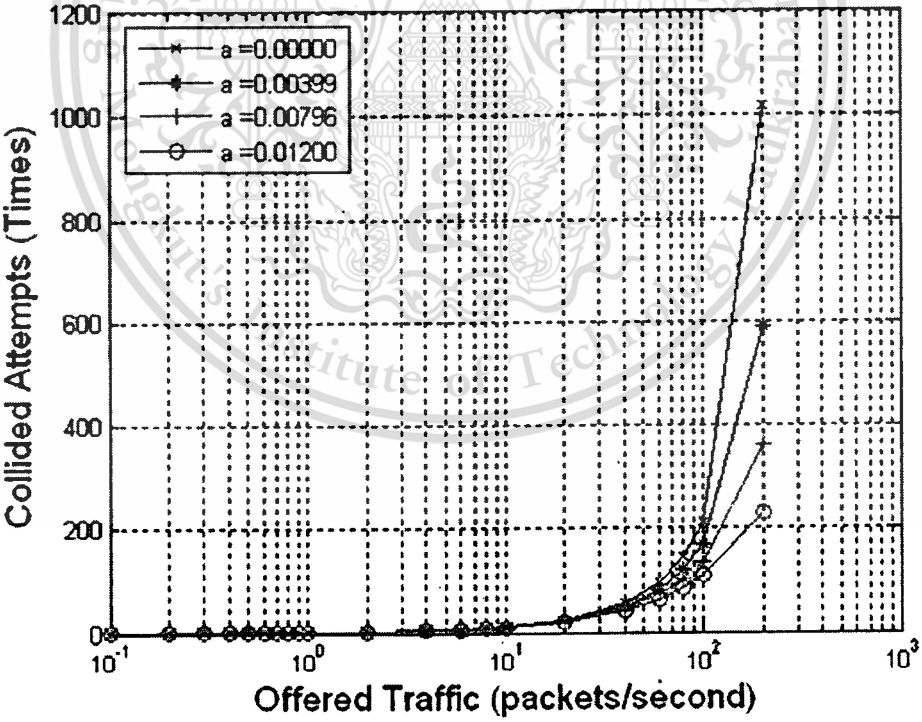

Figure 4.16d Collided attempts of modified slotted np-ISMA protocol with service area radius (r) = 1,000km

4. Relation between inhibited attempt times and offered traffic of the modified slotted np-ISMA protocol when varying the value of cover zone radius (r):

In figure 4.17, with cover zone radius r = 100km and offered traffic G = 200 packet/second, when the values of timing advance increased from 0% to 30%, 30% to 60% and 60% to 90%, the inhibited attempt times of modified slotted np-ISMA protocol decreased 31.71%, 44.70% and 75.59%, respectively. With the cover zone radius r = 100km and 1,000km, when the values of timing advance increased from 0% to 90%, the inhibited attempt times of modified slotted np-ISMA protocol decreased 90.79% and 96.40%, respectively. The summary of these simulation results is showed in table 4.12.

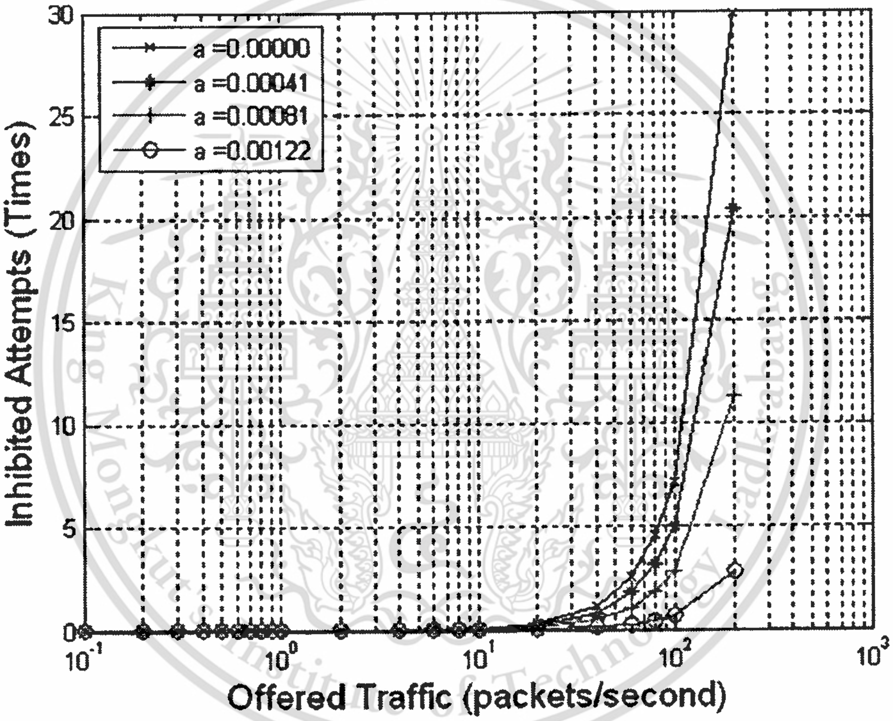

Figure 4.17a Inhibited attempts of modified slotted np-ISMA protocol with service area radius (r) = 100km

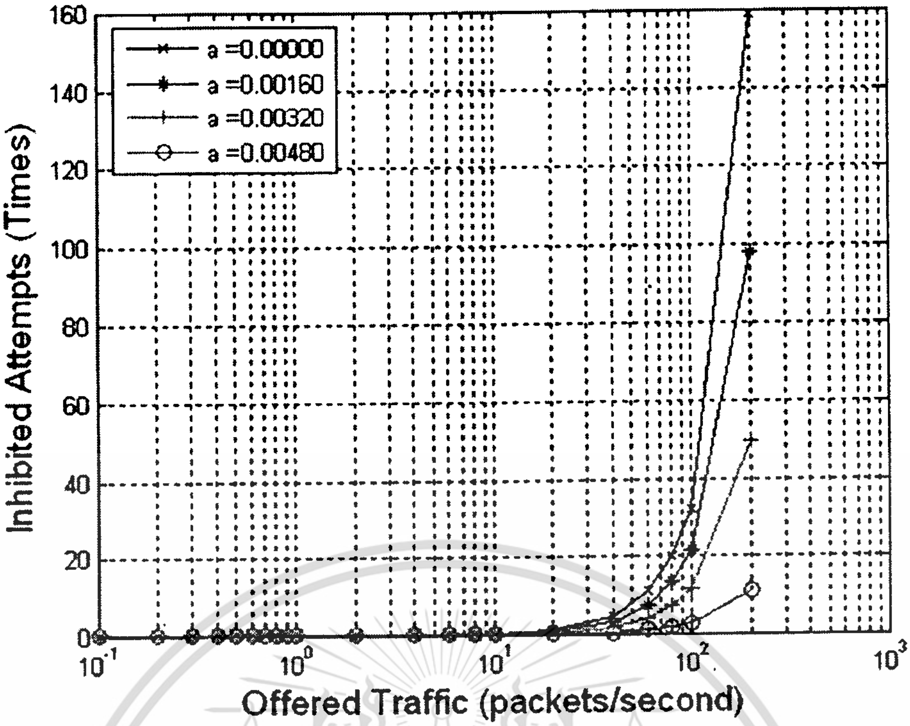

Figure 4.17b Inhibited attempts of modified slotted np-ISMA protocol with service area radius (r) = 400km

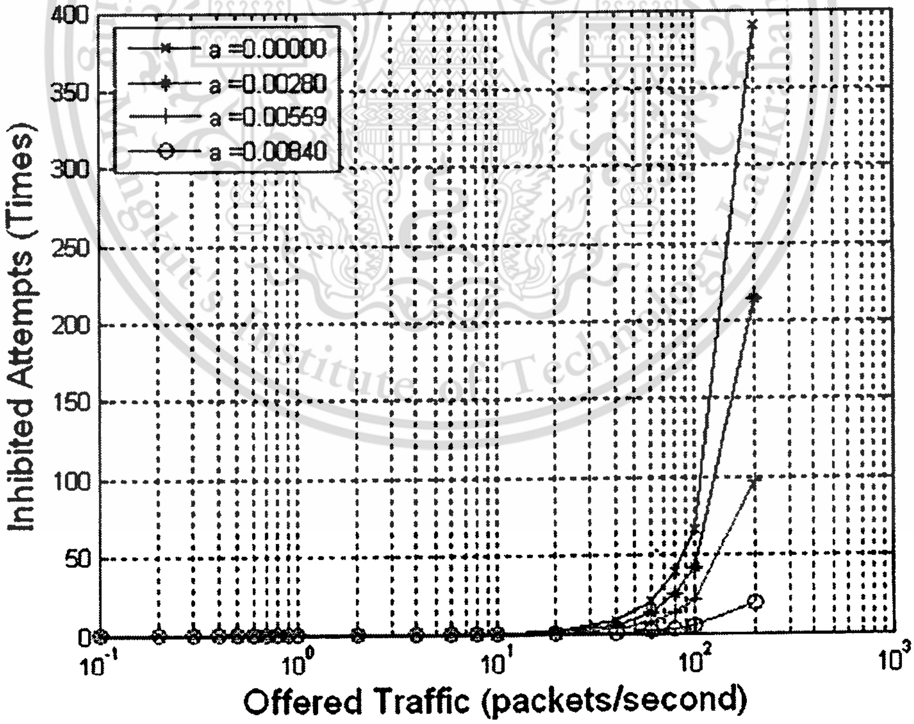

Figure 4.17c Inhibited attempts of modified slotted np-ISMA protocol with service area radius (r) = 700km

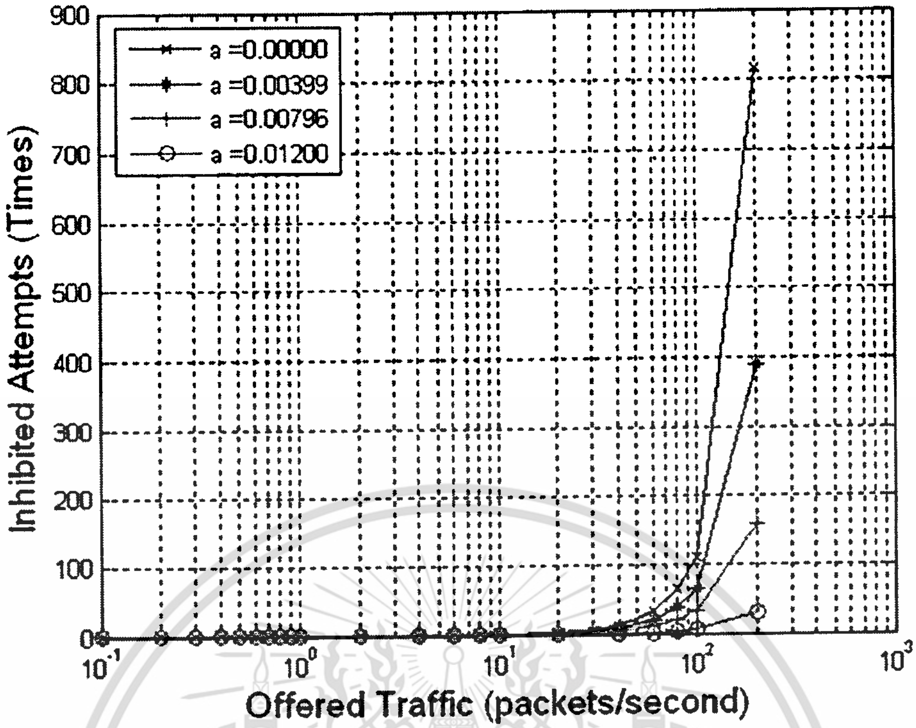

Figure 4.17d Inhibited attempts of modified slotted np-ISMA protocol with service area radius (r) = 1,000km

Table 4.12 Inhibited attempt of the modified slotted np-ISMA protocol with the varying values of cover zone radius (r), when the offered traffic (G) = 200packet/s

Cover zone Radius (r) [km]	Inhibited Attempt (times)			
	ISMA	ISMA +30%	ISMA +60%	ISMA +90%
100	29.8951	20.4155	11.2907	2.7556
400	158.6030	97.8918	49.7762	11.1249
700	389.5907	213.9826	97.8722	20.0000
1,000	815.7766	388.8658	157.4848	29.3662

4.3.2 Simulation results when varied the values of packet length

Table 4.13 shows the conditions of the simulation with the values of packet length (Mplen) are varied from 128 to 1,024 symbol.

Table 4.13 Simulation condition assumptions of the modified slotted np-ISMA protocol with the varying values of packet length (Mplen)

Symbol rate	Srate	256 ksymbol/second
Length of the packet	Mplen	128, 256, 512, 1,024 symbol
Inhibited time (normalized)	d	0.0013 -
Cover zone radius	r	100 km
High of the base station	-	100 km
Number of terminal	Mnum	300 -
Timing advance (% of Inhibited time)	a	0%, 30%, 60%, 90%

1. Relation between throughput and offered traffic of the modified slotted np-ISMA protocol when varying the value of packet length (Mplen):

Table 4.14 Throughput of the modified slotted np-ISMA protocol with the varying values of packet length (Mplen), when the offered traffic (G) = 200packet/s

Packet Length (Mplen) [symbol]	Throughput (normalized)			
	ISMA	ISMA +30%	ISMA +60%	ISMA +90%
128	0.8653	0.9028	0.9416	0.9814
256	0.9286	0.9482	0.9681	0.9882
512	0.9561	0.9677	0.9793	0.9910
1,024	0.9781	0.9831	0.9882	0.9933

Table 4.15 Maximum throughput of the modified slotted np-ISMA protocol with the varying values of packet length (Mplen)

Length of the packet (Mplen)	Maximum Throughput (normalized)			
	ISMA	ISMA +30%	ISMA +60%	ISMA +90%
128	0.9487	0.9567	0.9673	0.9833
256	0.9633	0.9694	0.9768	0.9882
512	0.9720	0.9766	0.9822	0.9910
1,024	0.9816	0.9841	0.9882	0.9933

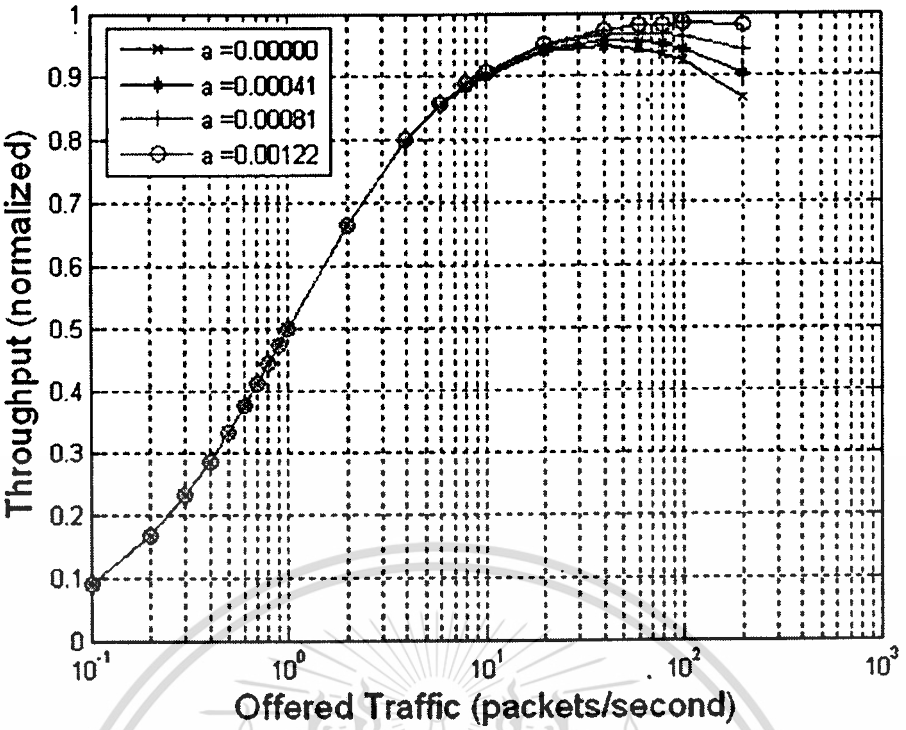

Figure 4.18a Throughput of modified slotted np-ISMA protocol with packet length (Mplen) = 128 symbol

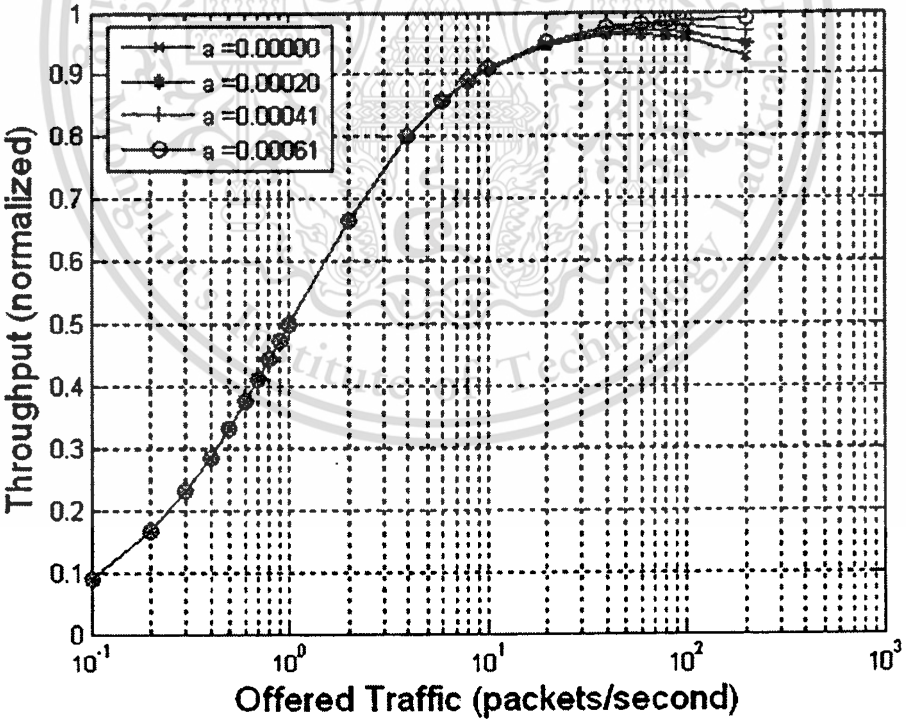

Figure 4.18b Throughput of modified slotted np-ISMA protocol with packet length (Mplen) = 256 symbol

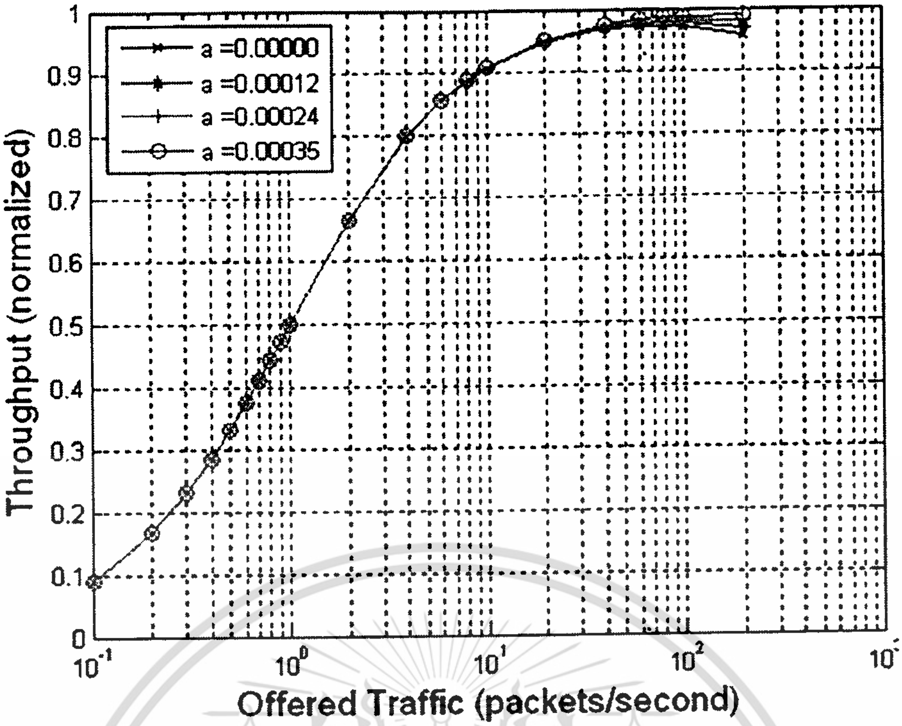

Figure 4.18c Throughput of modified slotted np-ISMA protocol with packet length (Mplen) = 512 symbol

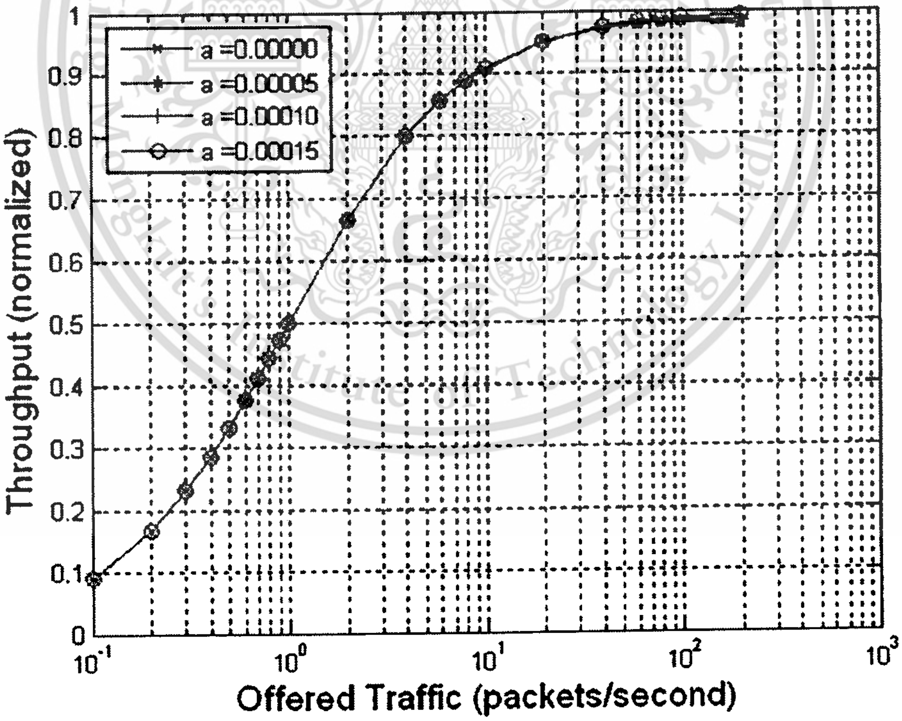

Figure 4.18d Throughput of modified slotted np-ISMA protocol with packet length (Mplen) = 1,024 symbol

In figure 4.18, with the packet length Mplen = 128 symbol and offered traffic G = 200 packet/second, when the values of timing advance increased from 0% to 30%, 30% to 60% and 60% to 90%, the throughputs of modified slotted np-ISMA protocol increased 4.34%, 4.29% and 4.23%, respectively. The maximum throughputs of modified slotted np-ISMA protocol increased 0.83%, 1.12% and 1.65%, respectively. With the packet length Mplen = 128 symbol and 1,024 symbol, when the values of timing advance increased from 0% to 90%, the throughputs of modified slotted np-ISMA protocol increased 13.42% and 1.55%, respectively. The maximum throughputs of modified slotted np-ISMA protocol increased 3.65% and 1.19%, respectively. The summary of these simulation results is showed in table 4.14 and table 4.15.

2. Relation between packet delay and offered traffic of the modified slotted np-ISMA protocol when varying the value of packet length (Mplen):

In figure 4.19, with the packet length Mplen = 128 symbol and offered traffic G = 200 packet/second, when the values of timing advance increased from 0% to 30%, 30% to 60% and 60% to 90%, the packet delays of modified slotted np-ISMA protocol decreased 4.22%, 4.17% and 4.12%, respectively. With the packet length Mplen = 128 symbol and 1,024 symbol, when the values of timing advance increased from 0% to 90%, the packet delays of modified slotted np-ISMA protocol decreased 12% and 1.56%, respectively. The summary of these simulation results is showed in table 4.16.

Table 4.16 Packet delay of the modified slotted np-ISMA protocol with the varying values of packet length (Mplen), when the offered traffic (G) = 200packet/s

Packet Length (Mplen) [symbol]	Packet Delay (normalized)			
	ISMA	ISMA +30%	ISMA +60%	ISMA +90%
128	0.1153	0.1104	0.1058	0.1015
256	0.2147	0.2102	0.2059	0.2016
512	0.3602	0.3558	0.3515	0.3473
1,024	0.8171	0.8128	0.8085	0.8043

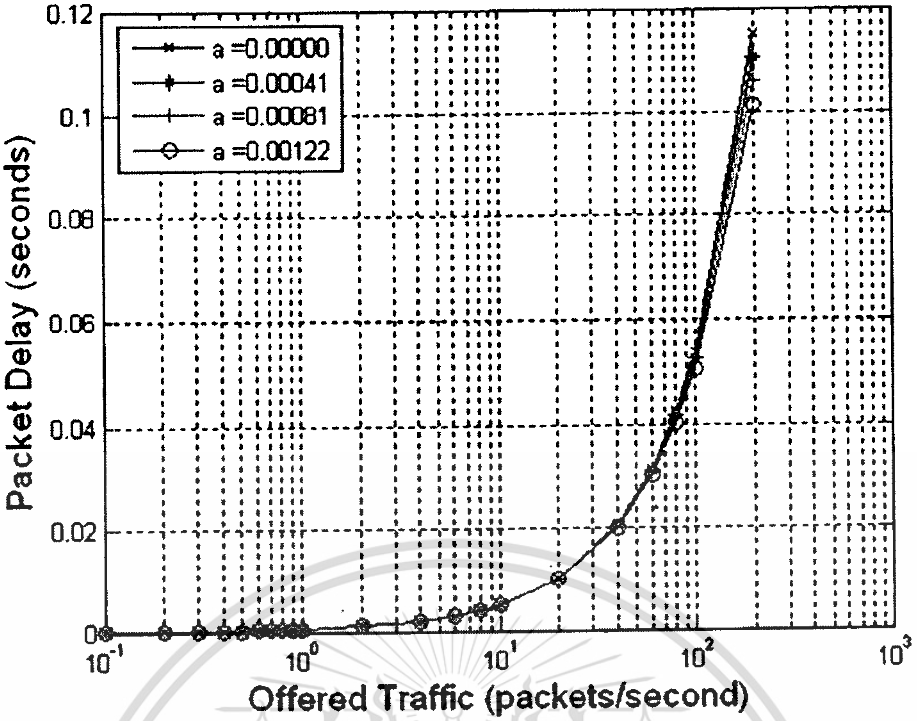

Figure 4.19a Packet delay of modified slotted np-ISMA protocol with packet length (Mplen) = 128 symbol

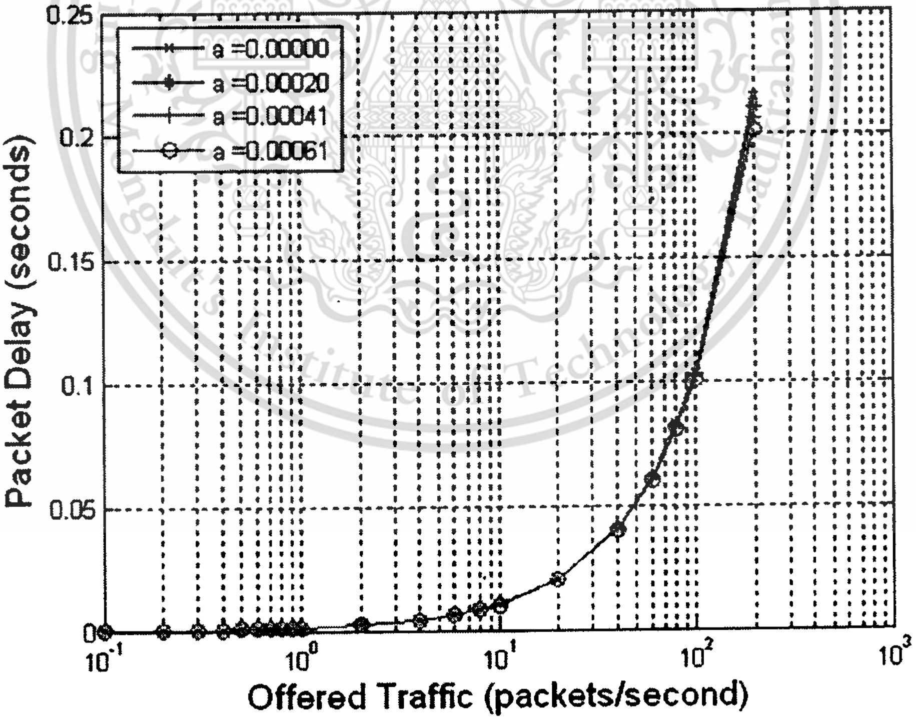

Figure 4.19b Packet delay of modified slotted np-ISMA protocol with packet length (Mplen) = 256 symbol

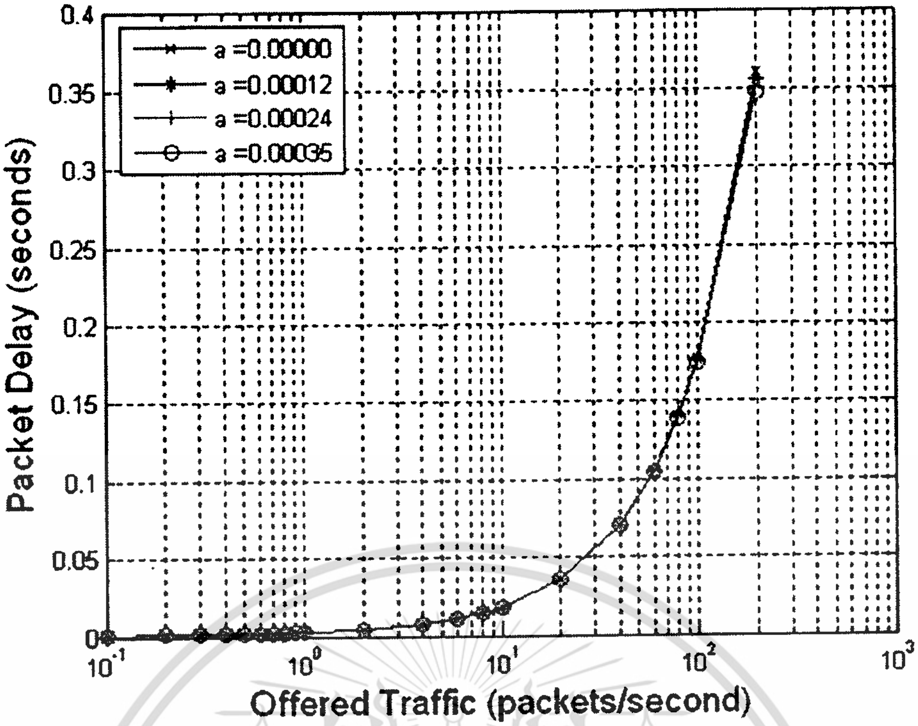

Figure 4.19c Packet delay of modified slotted np-ISMA protocol with packet length (Mplen) = 512 symbol

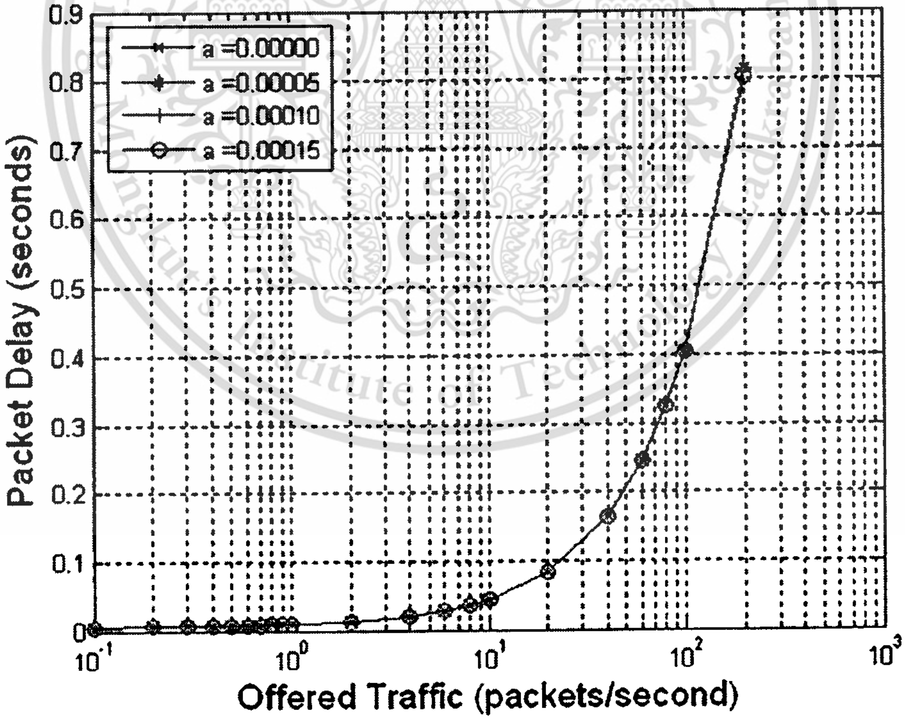

Figure 4.19d Packet delay of modified slotted np-ISMA protocol with packet length (Mplen) = 1,024 symbol

3. Relation between collided attempt times and offered traffic of the modified slotted np-ISMA protocol when varying the value of packet length (Mplen):

In figure 4.20, with packet length Mplen = 128 symbol and offered traffic G = 200 packet/second, when the values of timing advance increased from 0% to 30%, 30% to 60% and 60% to 90%, the collided attempt times of modified slotted np-ISMA protocol decreased 4.18%, 4.13% and 4.08%, respectively. With the packet length Mplen = 128 symbol and 1,024 symbol, when the values of timing advance increased from 0% to 90%, the collided attempt times of modified slotted np-ISMA protocol decreased 11.89% and 1.54%, respectively. The summary of these simulation results is showed in table 4.17.

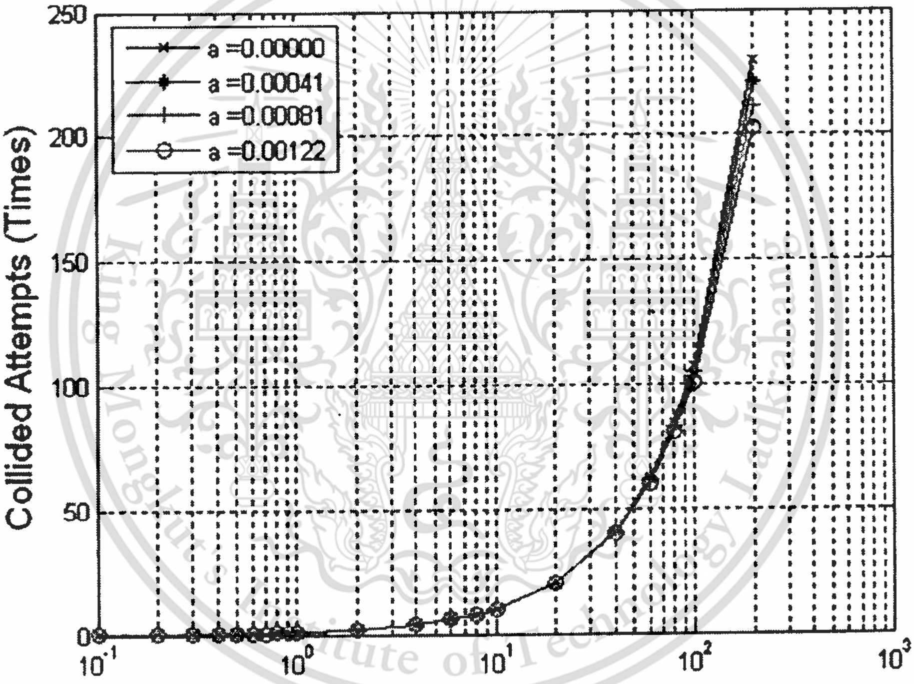

Figure 4.20a Collided attempts of modified slotted np-ISMA protocol with packet length (Mplen) = 128 symbol

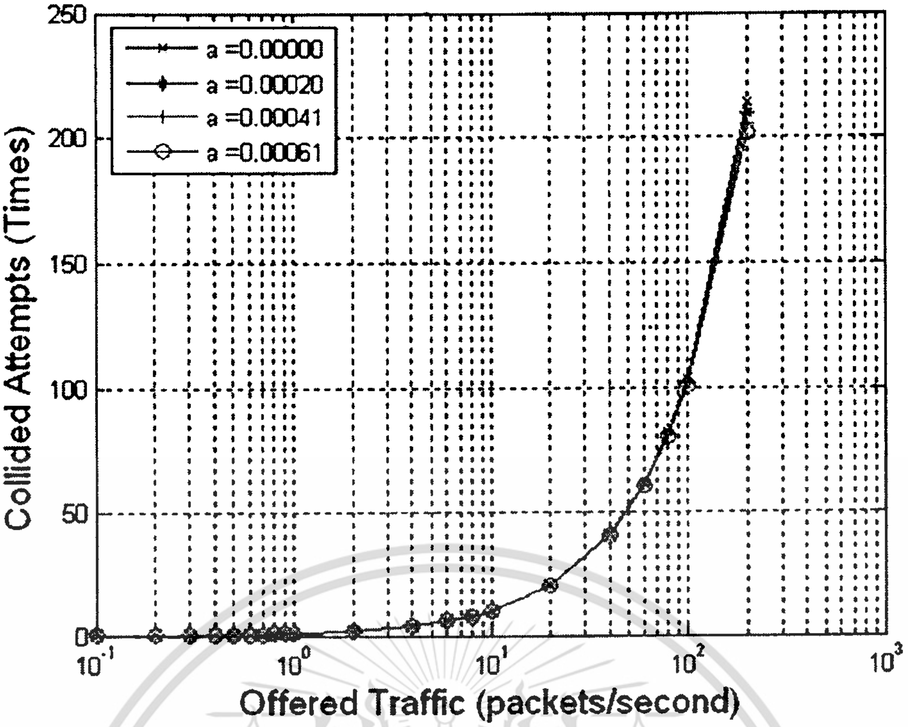

Figure 4.20b Collided attempts of modified slotted np-ISMA protocol with packet length (Mplen) = 256 symbol

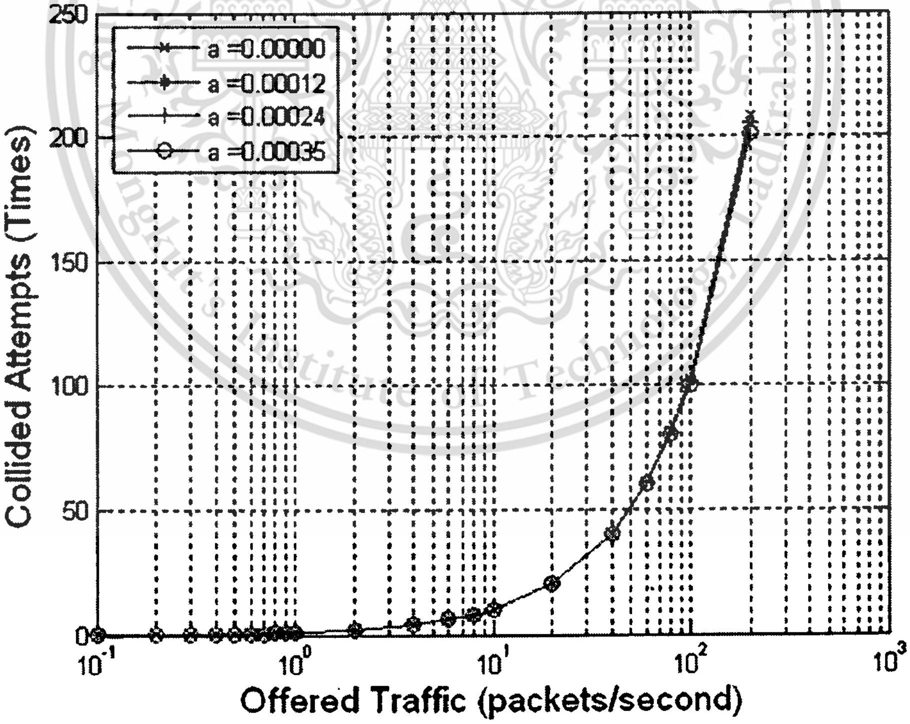

Figure 4.20c Collided attempts of modified slotted np-ISMA protocol with packet length (Mplen) = 512 symbol

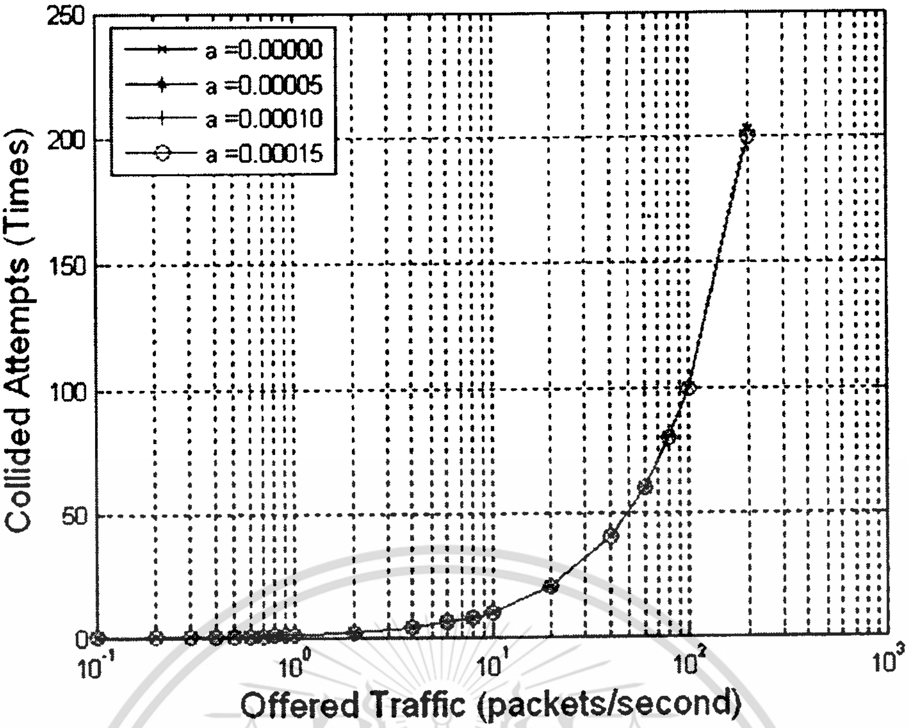

Figure 4.20d Collided attempts of modified slotted np-ISMA protocol with packet length (Mplen) = 1,024 symbol

Table 4.17 Collided attempt of the modified slotted np-ISMA protocol with the varying values of packet length (Mplen), when the offered traffic(G) = 200packet/s

Packet Length (Mplen) [symbol]	Collided Attempt (times)			
	ISMA	ISMA +30%	ISMA +60%	ISMA +90%
128	230.1258	220.5106	211.3982	202.7698
256	214.3555	209.9180	205.5896	201.3796
512	208.1622	205.6683	203.2108	200.7968
1,024	203.4728	202.4185	201.3759	200.3435

4. Relation between inhibited attempt times and offered traffic of the modified slotted np-ISMA protocol when varying the value of packet length (Mplen):

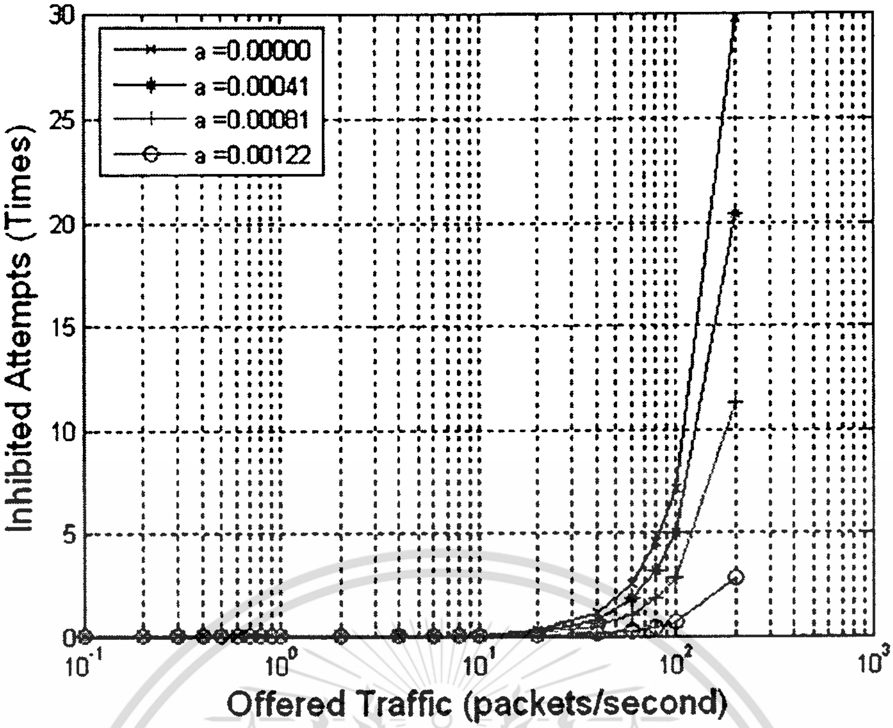

Figure 4.21a Inhibited attempts of modified slotted np-ISMA protocol with packet length (Mplen) = 128 symbol

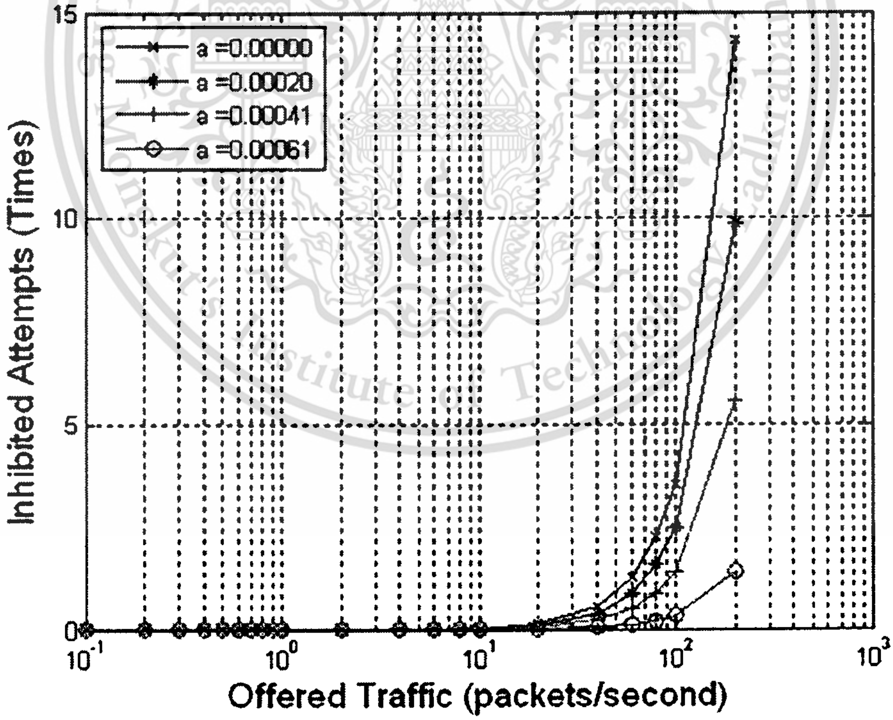

Figure 4.21b Inhibited attempts of modified slotted np-ISMA protocol with packet length (Mplen) = 256 symbol

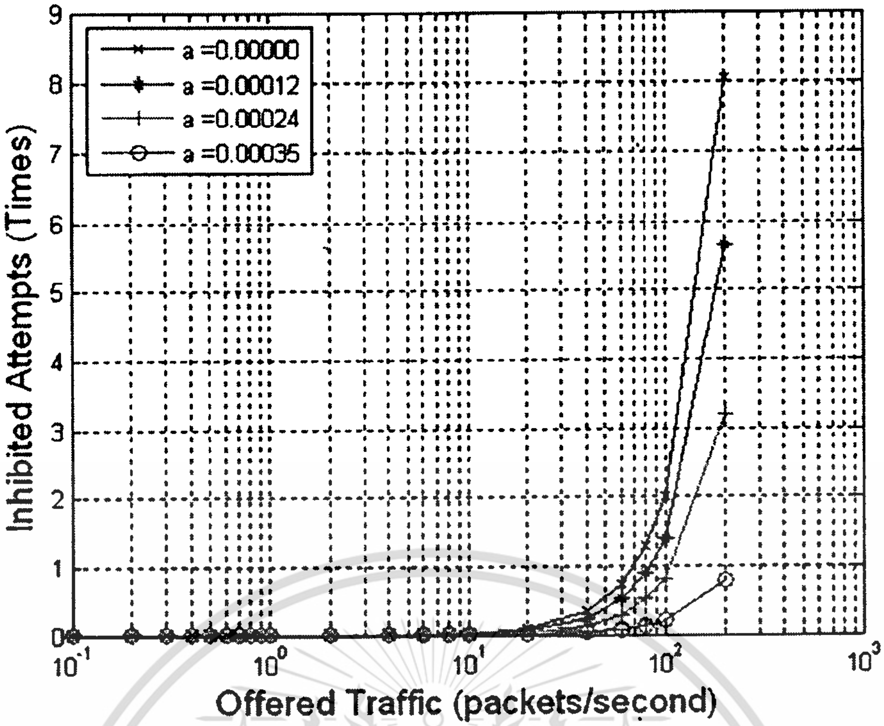

Figure 4.21c Inhibited attempts of modified slotted np-ISMA protocol with packet length (Mplen) = 512 symbol

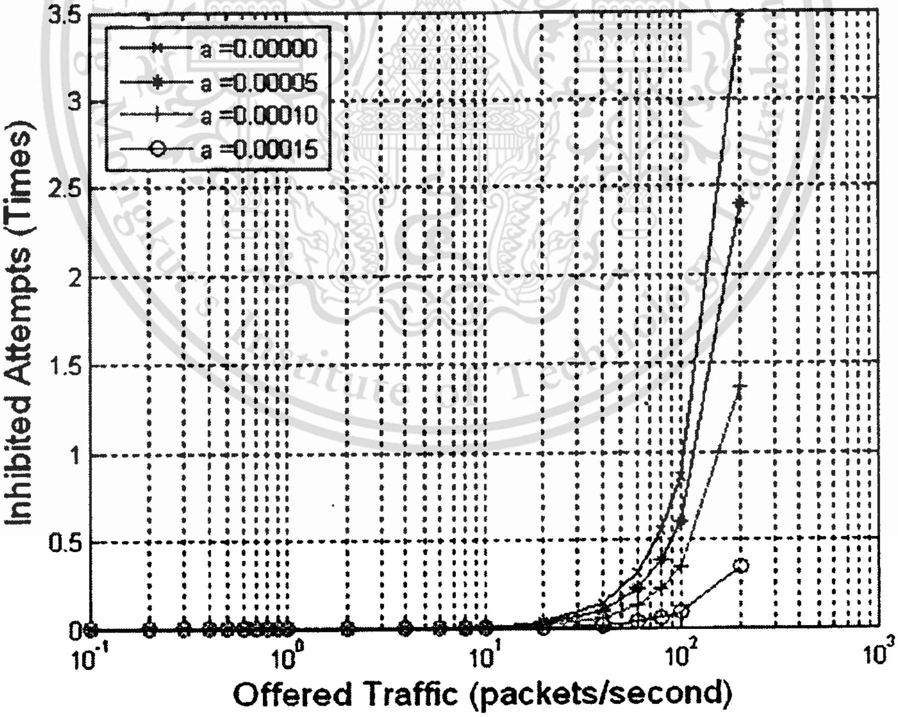

Figure 4.21d Inhibited attempts of modified slotted np-ISMA protocol with packet length (Mplen) = 1,024 symbol

In figure 4.21, with packet length Mplen = 128 symbol and offered traffic G = 200 packet/second, when the values of timing advance increased from 0% to 30%, 30% to 60% and 60% to 90%, the inhibited attempt times of modified slotted np-ISMA protocol decreased 31.50%, 44.49% and 75.74%, respectively. With packet length Mplen = 128 symbol and 1,024 symbol, when the values of timing advance increased from 0% to 90%, the inhibited attempt times of modified slotted np-ISMA protocol decreased 90.78% and 90.10%, respectively. The summary of these simulation results is showed in table 4.18.

Table 4.18 Inhibited attempt of the modified slotted np-ISMA protocol with the varying values of packet length (Mplen), when the offered traffic(G) = 200 packet/s

Packet Length (Mplen) [symbol]	Inhibited Attempt (times)			
	ISMA	ISMA +30%	ISMA +60%	ISMA +90%
128	29.7935	20.4071	11.3270	2.7477
256	14.3113	9.8618	5.5326	1.3718
512	8.0497	5.6294	3.1911	0.7883
1,024	3.4543	2.4022	1.3718	0.3420

4.3.3 Simulation results when varied the values of symbol rate

Table 4.19 shows the conditions of the simulation with the values of symbol rate (Srate) are varied from 256 to 2,048 ksymbol/second.

Table 4.19 Simulation condition assumptions of the modified slotted np-ISMA protocol with the varying values of symbol rate (Srate)

Symbol rate	Srate	256, 512, 1,024, 2,048 ksymbol/second	
Length of the packet	Mplen	128	symbol
Inhibited time (normalized)	d	0.0013	-
Cover zone radius	r	100	km
High of the base station	-	100	km
Number of terminal	Mnum	300	-
Timing advance (% of Inhibited time)	a	0%, 30%, 60%, 90%	

1. Relation between throughput and offered traffic of the modified slotted np-ISMA protocol when varying the value of packet length (Mplen):

In figure 4.22, with the symbol rate Srate = 256 ksymbol/second and offered traffic G = 200 packet/second, when the values of timing advance increased from 0% to 30%, 30% to 60% and 60% to 90%, the throughputs of modified slotted np-ISMA protocol increased 4.36%, 4.27% and 4.23%, respectively. The maximum throughputs of modified slotted np-ISMA protocol increased 0.85%, 1.11% and 1.65%, respectively. With the symbol rate Srate = 256 ksymbol/second and 1,024 ksymbol/second, when the values of timing advance increased from 0% to 90%, the throughputs of modified slotted np-ISMA protocol increased 13.43% and 223.27%, respectively. The maximum throughputs of modified slotted np-ISMA protocol increased 3.65% and 11.42%, respectively. The summary of these simulation results is showed in table 4.20 and table 4.21.

Table 4.20 Throughput of the modified slotted np-ISMA protocol with the varying values of symbol rate (Srate), when the offered traffic (G) = 200 packet/s

Symbol Rate (Srate) [ksps]	Throughput (normalized)			
	ISMA	ISMA +30%	ISMA +60%	ISMA +90%
256	0.8653	0.9030	0.9417	0.9815
512	0.7485	0.8169	0.8903	0.9680
1,024	0.5487	0.6628	0.7932	0.9416
2,048	0.2754	0.4206	0.6226	0.8903

Table 4.21 Maximum throughput of the modified slotted np-ISMA protocol with the varying values of symbol rate (Srate)

Symbol Rate (Srate) [ksps]	Maximum Throughput (normalized)			
	ISMA	ISMA +30%	ISMA +60%	ISMA +90%
256	0.9487	0.9567	0.9674	0.9833
512	0.9256	0.9380	0.9540	0.9768
1,024	0.8992	0.9149	0.9327	0.9674
2,048	0.8562	0.8784	0.9096	0.9540

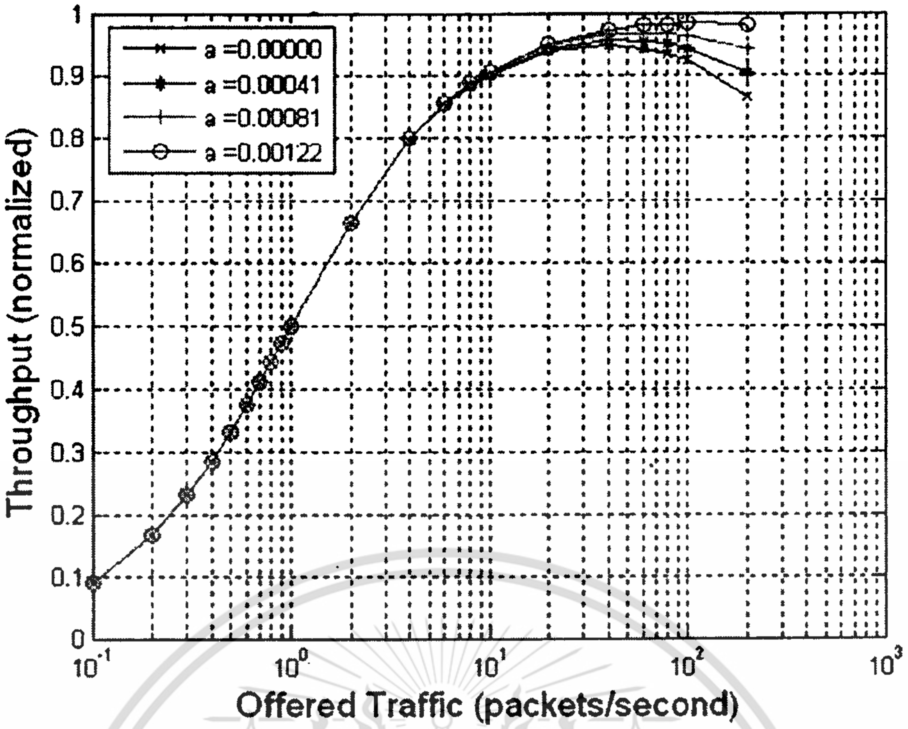

Figure 4.22a Throughput of modified slotted np-ISMA protocol with symbol rate (Srate) = 256 ksymbol/second

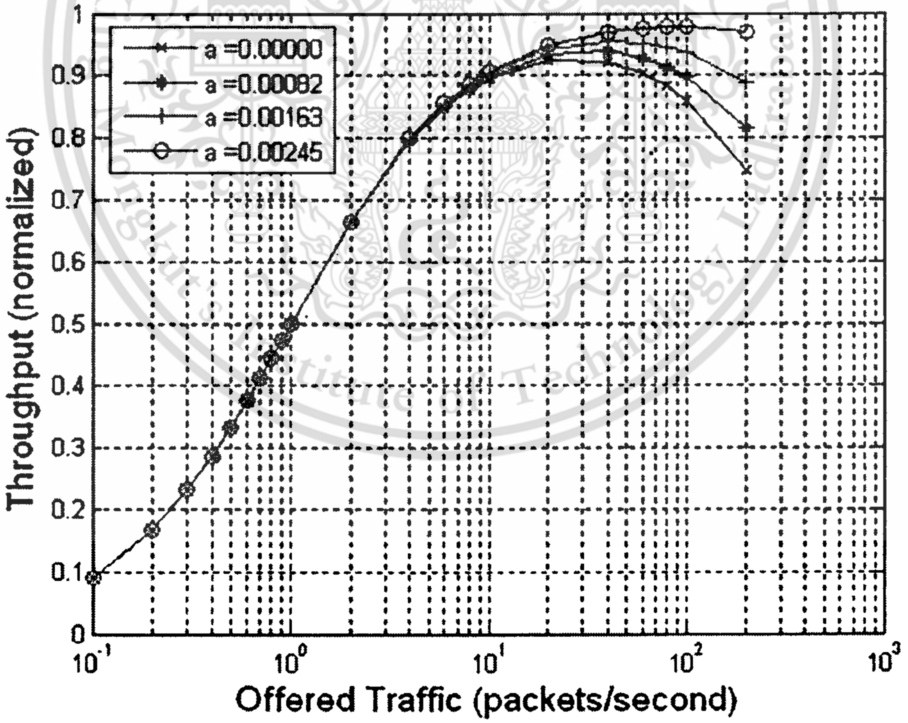

Figure 4.22b Throughput of modified slotted np-ISMA protocol with symbol rate (Srate) = 512 ksymbol/second

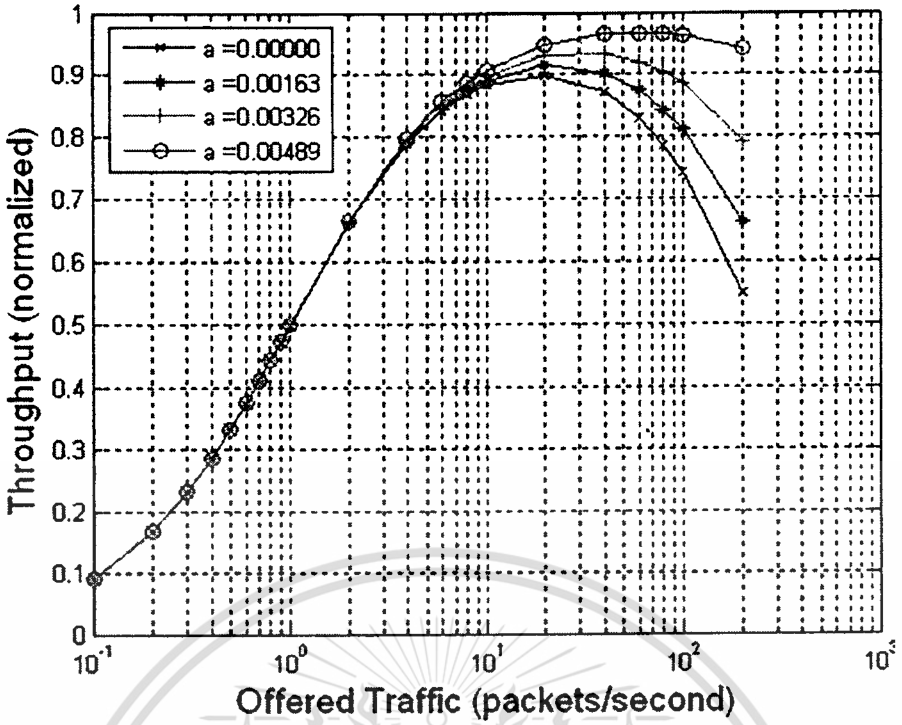

Figure 4.22c Throughput of modified slotted np-ISMA protocol with symbol rate (Srate) = 1,024 ksymbol/second

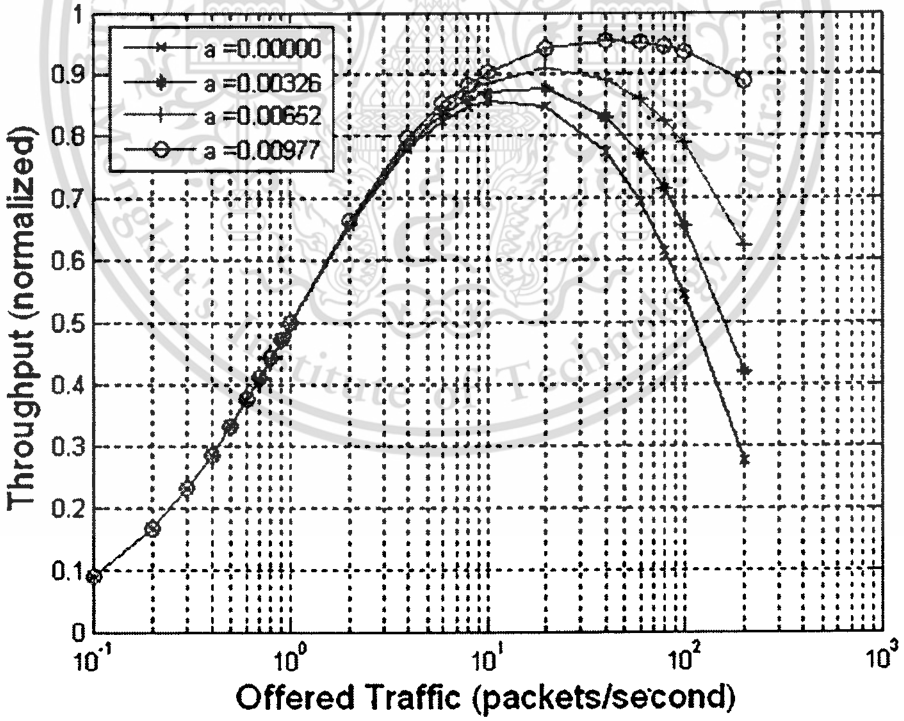

Figure 4.22d Throughput of modified slotted np-ISMA protocol with symbol rate (Srate) = 2,048 ksymbol/second

2. Relation between packet delay and offered traffic of the modified slotted np-ISMA protocol when varying the value of symbol rate (Srate):

In figure 4.23, with the symbol rate Srate = 256 ksymbol/second and offered traffic G = 200 packet/second, when the values of timing advance increased from 0% to 30%, 30% to 60% and 60% to 90%, the packet delays of modified slotted np-ISMA protocol decreased 4.24%, 4.16% and 4.12%, respectively. With the symbol rate Srate = 256 ksymbol/second and 1,024 ksymbol/second, when the values of timing advance increased from 0% to 90%, the packet delays of modified slotted np-ISMA protocol decreased 12% and 69.46%, respectively. The summary of these simulation results is showed in table 4.22.

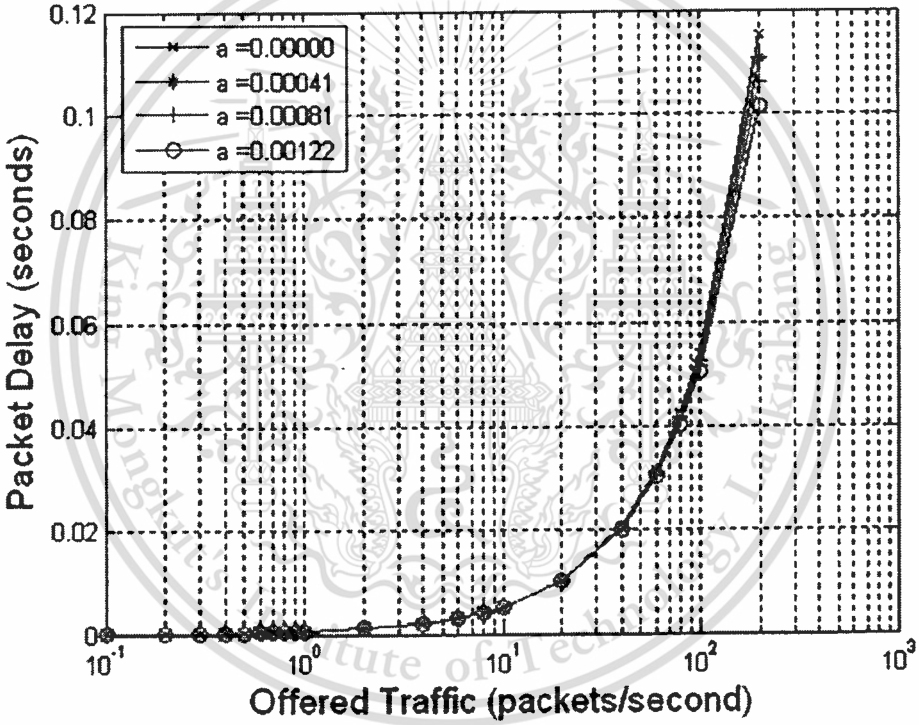

Figure 4.23a Packet delay of modified slotted np-ISMA protocol with symbol rate (Srate) = 256 ksymbol/second

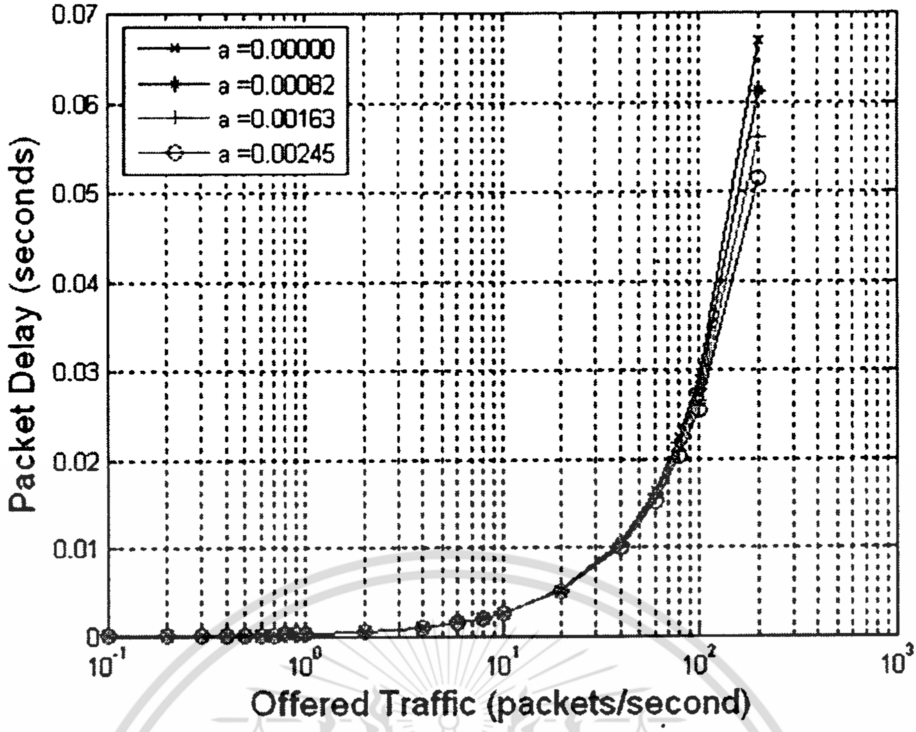

Figure 4.23b Packet delay of modified slotted np-ISMA protocol with symbol rate (Srate) = 512 ksymbol/second

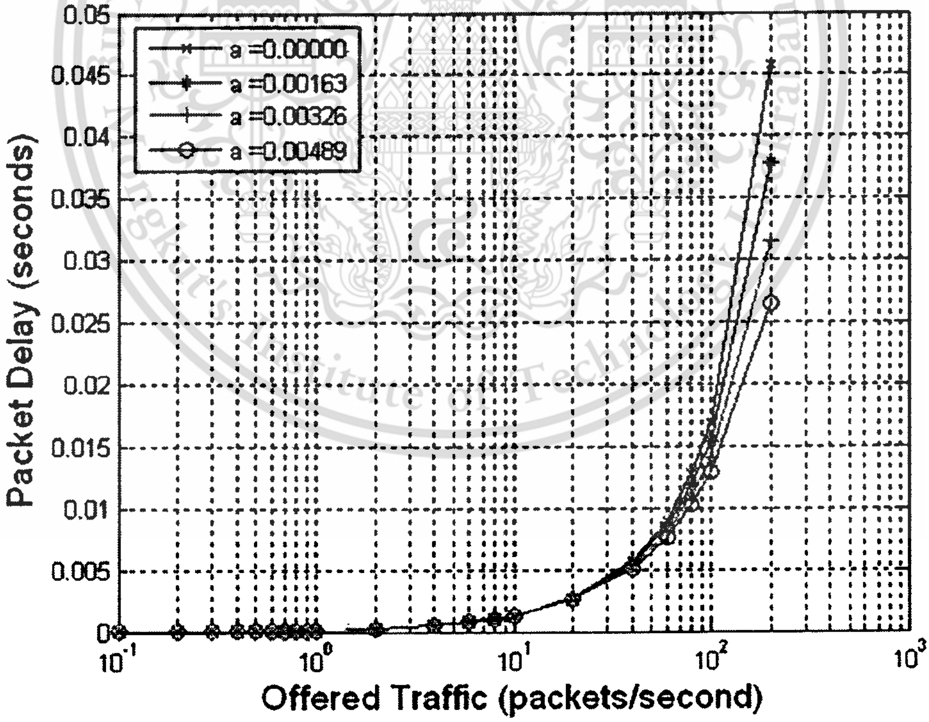

Figure 4.23c Packet delay of modified slotted np-ISMA protocol with symbol rate (Srate) = 1,024 ksymbol/second

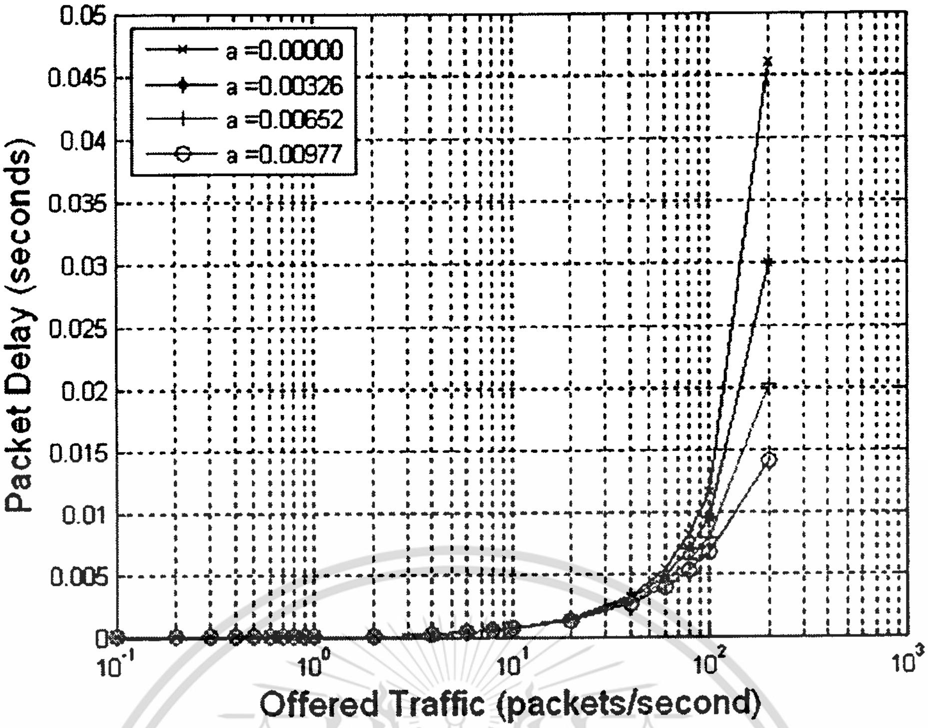

Figure 4.23d Packet delay of modified slotted np-ISMA protocol with symbol rate (Srate) = 2,048 ksymbol/second

Table 4.22 Packet delay of the modified slotted np-ISMA protocol with the varying values of symbol rate (Srate), when the offered traffic (G) = 200 packet/s

Symbol Rate (Srate) [ksps]	Packet Delay (normalized)			
	ISMA	ISMA +30%	ISMA +60%	ISMA +90%
256	0.1153	0.1104	0.1058	0.1015
512	0.0668	0.0611	0.0560	0.0514
1,024	0.0458	0.0378	0.0315	0.0265
2,048	0.0460	0.0300	0.0202	0.0140

3. Relation between collided attempt times and offered traffic of the modified slotted np-ISMA protocol when varying the value of symbol rate (Srate):

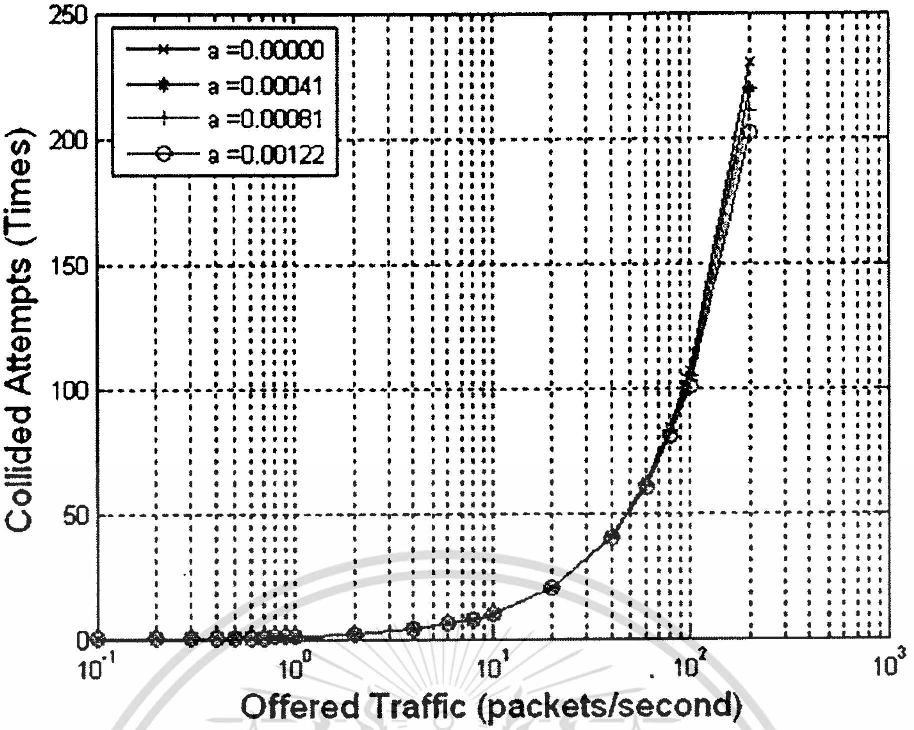

Figure 4.24a Collided attempts of modified slotted np-ISMA protocol with symbol rate (Srate) = 256 ksymbol/second

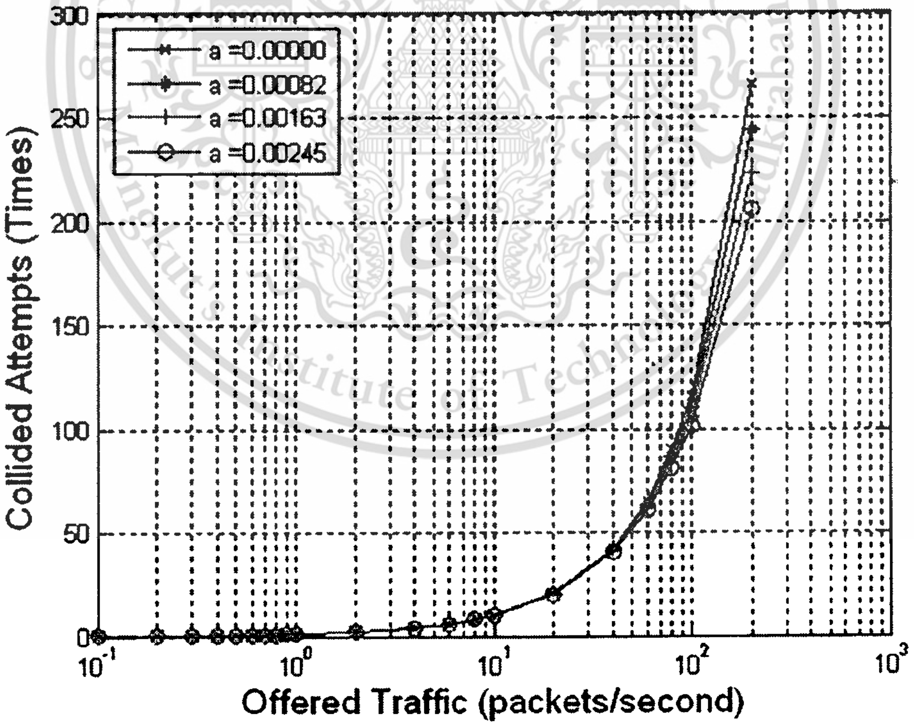

Figure 4.24b Collided attempts of modified slotted np-ISMA protocol with symbol rate (Srate) = 512 ksymbol/second

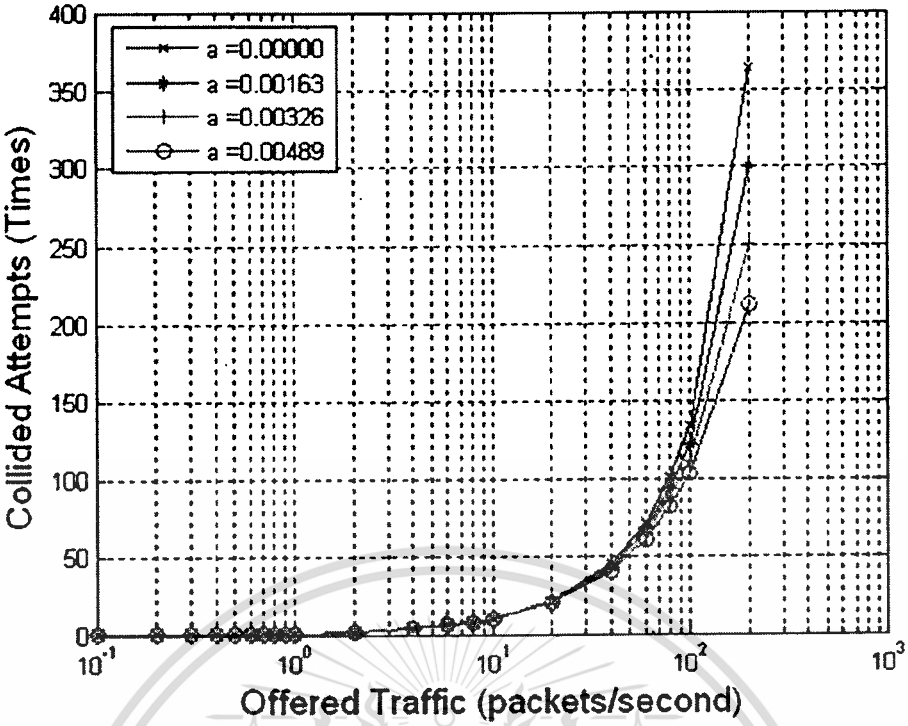

Figure 4.24c Collided attempts of modified slotted np-ISMA protocol with symbol rate (Srate) = 1,024 ksymbol/second

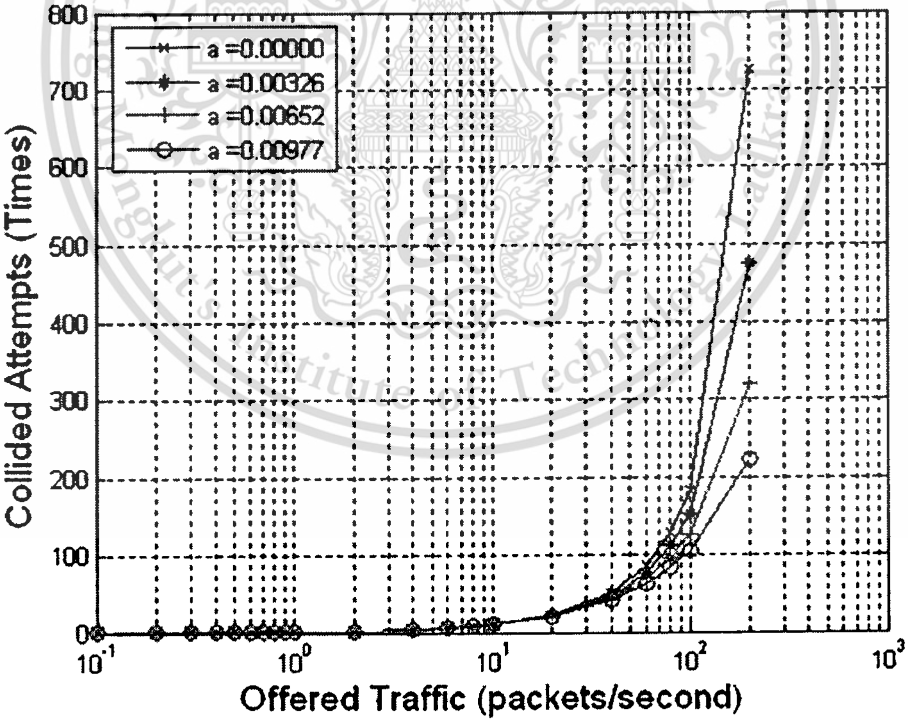

Figure 4.24d Collided attempts of modified slotted np-ISMA protocol with symbol rate (Srate) = 2,048 ksymbol/second

In figure 4.24, with symbol rate Srate = 256 ksymbol/second and offered traffic G = 200 packet/second, when the values of timing advance increased from 0% to 30%, 30% to 60% and 60% to 90%, the collided attempt times of modified slotted np-ISMA protocol decreased 4.2%, 4.12% and 4.07%, respectively. With the symbol rate Srate = 256 ksymbol/second and 1,024 ksymbol/second, when the values of timing advance increased from 0% to 90%, the collided attempt times of modified slotted np-ISMA protocol decreased 11.89% and 69.16%, respectively. The summary of these simulation results is showed in table 4.23.

Table 4.23 Collided attempt of the modified slotted np-ISMA protocol with the varying values of symbol rate (Srate), when the offered traffic (G) = 200 packet/s

Symbol Rate (Srate) [ksps]	Collided Attempt (times)			
	ISMA	ISMA +30%	ISMA +60%	ISMA +90%
256	230.1258	220.4600	211.3812	202.7678
512	266.1862	243.8195	223.6234	205.5907
1,024	363.4437	300.7452	251.1185	211.3829
2,048	725.1199	474.4661	320.1981	223.6197

4. Relation between inhibited attempt times and offered traffic of the modified slotted np-ISMA protocol when varying the value of symbol rate (Srate):

In figure 4.25, with the symbol rate Srate = 256 ksymbol/second and offered traffic G = 200 packet/second, when the values of timing advance increased from 0% to 30%, 30% to 60% and 60% to 90%, the inhibited attempt times of modified slotted np-ISMA protocol decreased 32.09%, 44.38% and 75.68%, respectively. With the symbol rate Srate = 256 ksymbol/second and 1,024 ksymbol/second, when the values of timing advance increased from 0% to 90%, the inhibited attempt times of modified slotted np-ISMA protocol decreased 90.81% and 95.51%, respectively. The summary of these simulation results is showed in table 4.24.

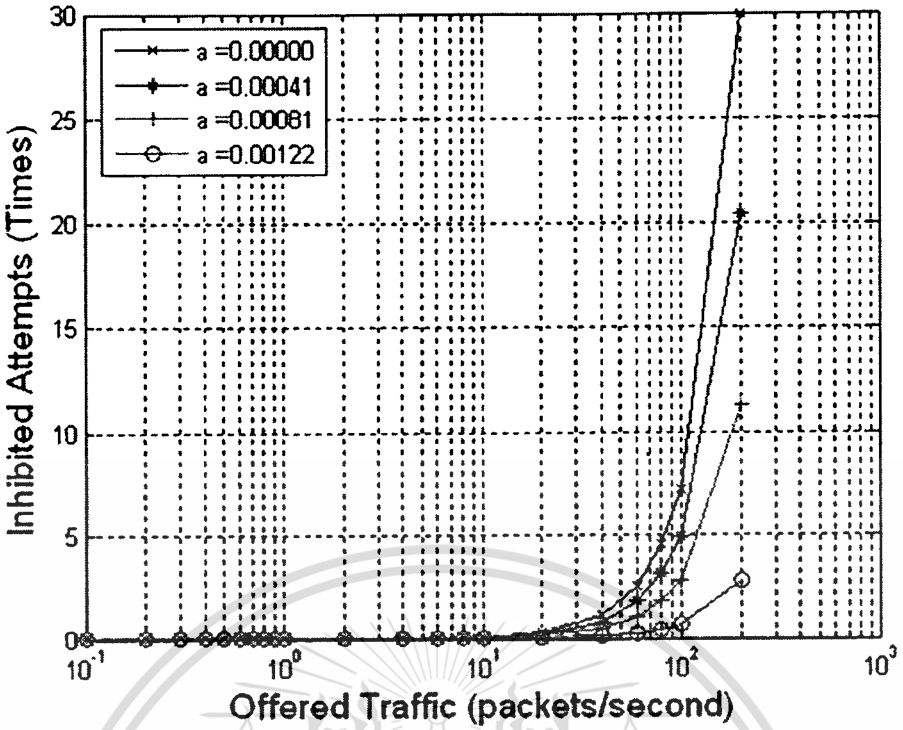

Figure 4.25a Inhibited attempts of modified slotted np-ISMA protocol with symbol rate (Srate) = 256 ksymbol/second

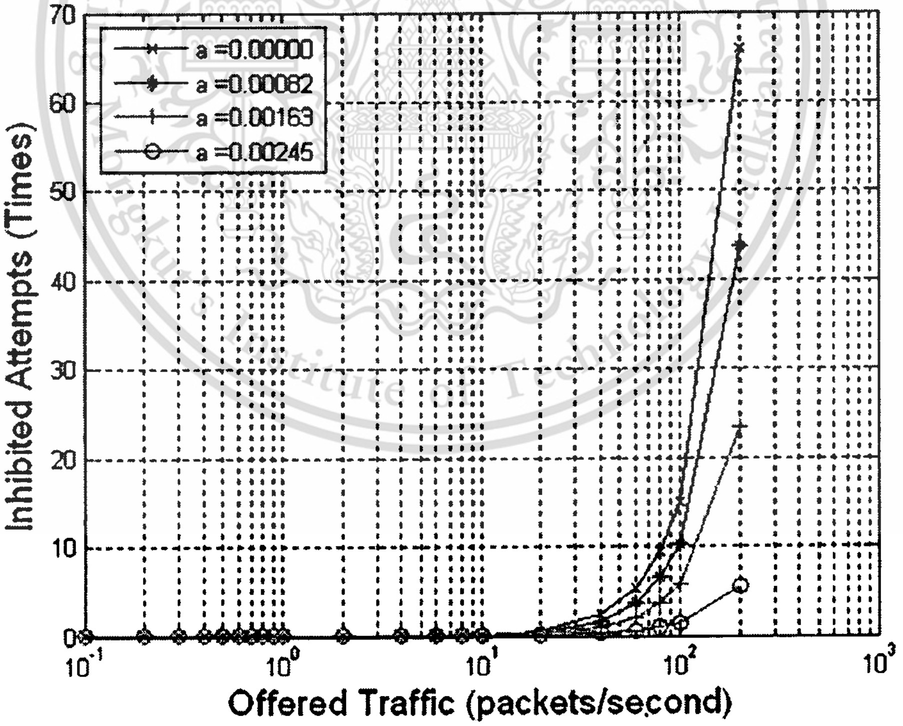

Figure 4.25b Inhibited attempts of modified slotted np-ISMA protocol with symbol rate (Srate) = 512 ksymbol/second

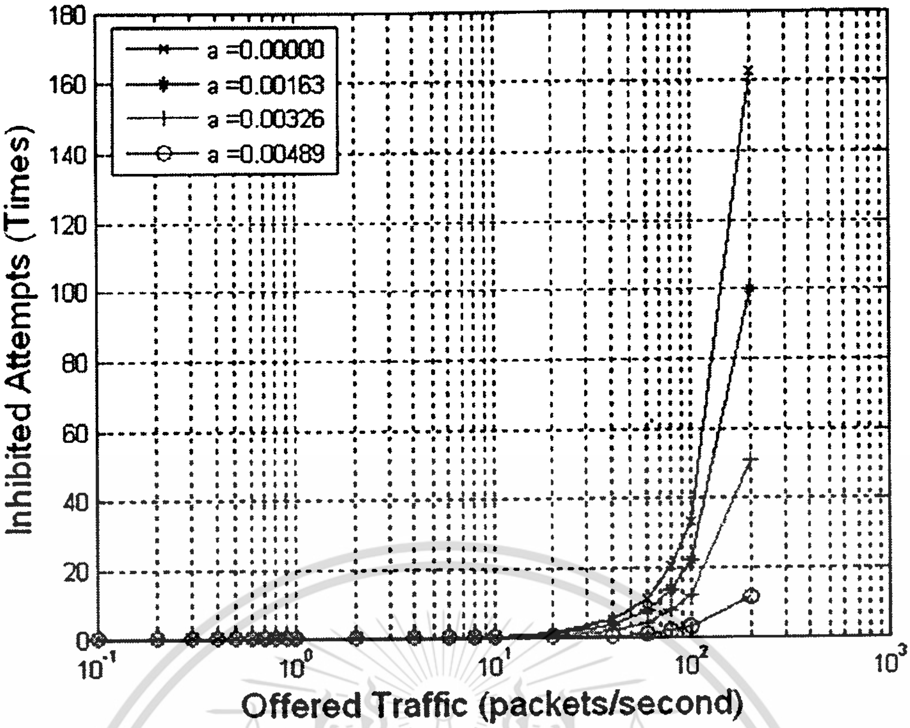

Figure 4.25c Inhibited attempts of modified slotted np-ISMA protocol with symbol rate (Srate) = 1,024 ksymbol/second

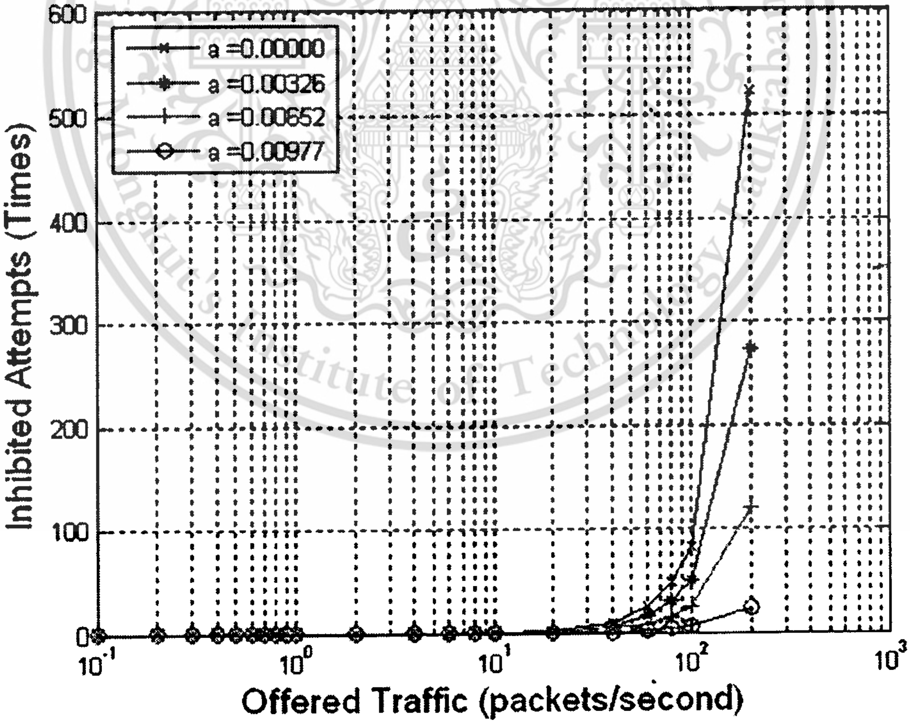

Figure 4.25d Inhibited attempts of modified slotted np-ISMA protocol with symbol rate (Srate) = 2,048 ksymbol/second

Table 4.24 Inhibited attempt of the modified slotted np-ISMA protocol with the varying values of symbol rate (Srate), when the offered traffic (G) = 200 packet/s

Symbol Rate (Srate) [ksps]	Inhibited Attempt (times)			
	ISMA	ISMA +30%	ISMA +60%	ISMA +90%
256	29.9837	20.3621	11.3258	2.7541
512	65.8908	43.6173	23.5108	5.5632
1,024	162.8040	100.3173	50.8852	11.3275
2,048	523.6663	273.5184	119.7009	23.5072

4.3.4 Conclusions

Through all of the simulation results above, we can conclude that the modified slotted non persistent ISMA protocol have the better performance than the original slotted non persistent ISMA protocol.

The performance of the modified slotted non persistent ISMA protocol will be increased when value of the timing advance factor is increased.

Further more, the performance of the modified slotted non persistent ISMA protocol also be increased when the service are radius is decreased, the length of the packet is decreased, and the symbol rate is decreased.

4.4 Compare the simulation results of the modified slotted non persistent ISMA protocol and the slotted ALOHA protocol:

In this part, we will evaluate the performance of modified slotted non persistent ISMA protocol compare with the slotted ALOHA protocol by the simulation throughputs of this system.

4.4.1 Simulation results when varied the value of cover zone radius

Table 4.25 shows the conditions of the simulation with the values of cover zone radius (r) are varied from 100 to 1,000 km.

Table 4.25 Simulation condition assumptions of the modified slotted np-ISMA protocol with the varying values of cover zone radius (r)

Symbol rate	Srate	256	ksymbol/second
Length of the packet	Mplen	128	symbol
Inhibited time (normalized)	d	0.001	-
Cover zone radius	r	100, 400, 700, 1,000 km	
High of the base station	z	1,000	km
Number of terminal	Mnum	300	-
Timing advance (% of Inhibited time)	a	90%, 99%, 99.9%, 99.99%	

Figures 4.26a, 4.26b, 4.26c and 4.26d show the relations between throughput and offered traffic of the modified slotted non persistent ISMA protocol and the slotted ALOHA protocol when the cover zone radius r = 100, 400, 700 and 1,000 km, respectively.

We can see in these figures that the throughput of the modified slotted non persistent ISMA protocol increases when the cover zone radius decreases and the timing advance increases. And the throughput of the modified slotted non persistent ISMA protocol always higher then that of the slotted ALOHA protocol when the timing advance is over 99% of the inhibited time duration. The simulation results summary is shown on table 4.26.

Table 4.26 Maximum throughput of the modified slotted np-ISMA protocol with the varying values of cover zone radius (r)

Cover Zone Radius (r) [km]	Maximum Throughput (normalized)			
	100	400	700	1,000
Slotted ALOHA	0.3679	0.3679	0.3679	0.3679
ISMA+90%	0.1116	0.1101	0.1069	0.1024
ISMA +99%	0.4582	0.4563	0.4497	0.4398
ISMA +99.9%	0.7877	0.7859	0.7821	0.7764
ISMA +99.99%	0.9286	0. 9280	0.9267	0.9248

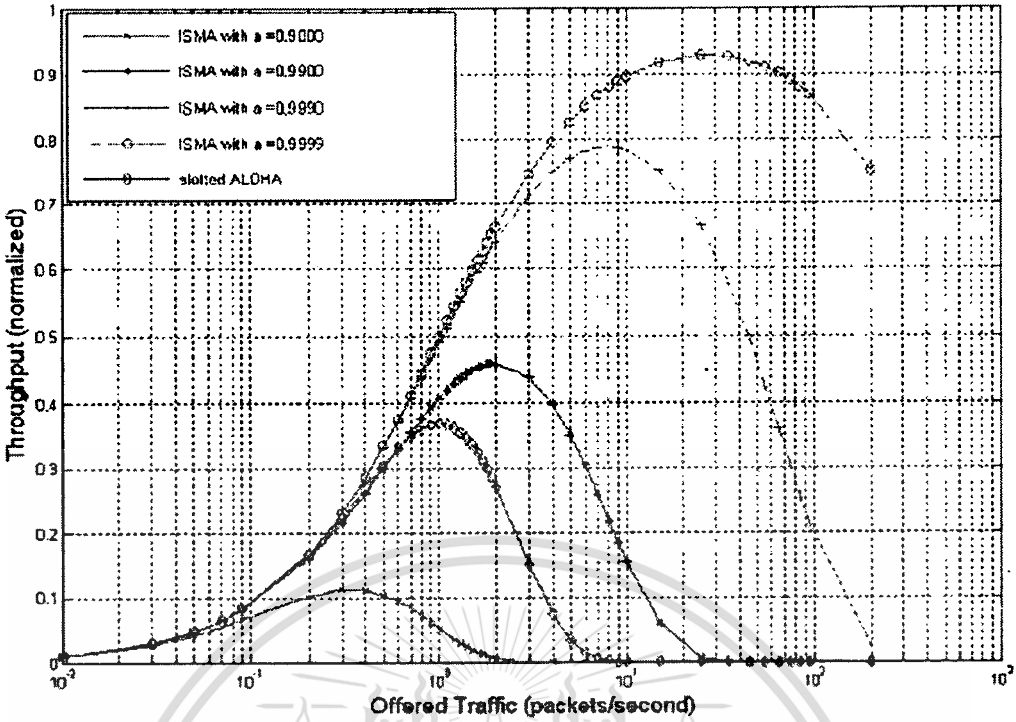

Figure 4.26a Throughput of modified slotted np-ISMA protocol and slotted ALOHA protocol with cover zone radius (r) = 100 km

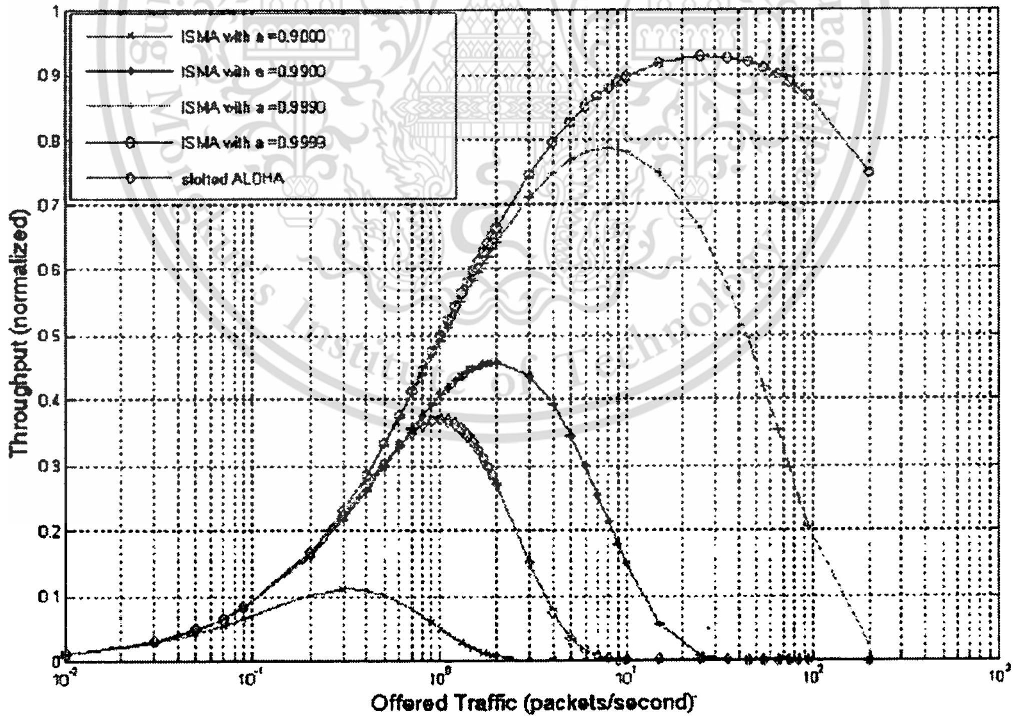

Figure 4.26b Throughput of modified slotted np-ISMA protocol and slotted ALOHA protocol with cover zone radius (r) = 400 km

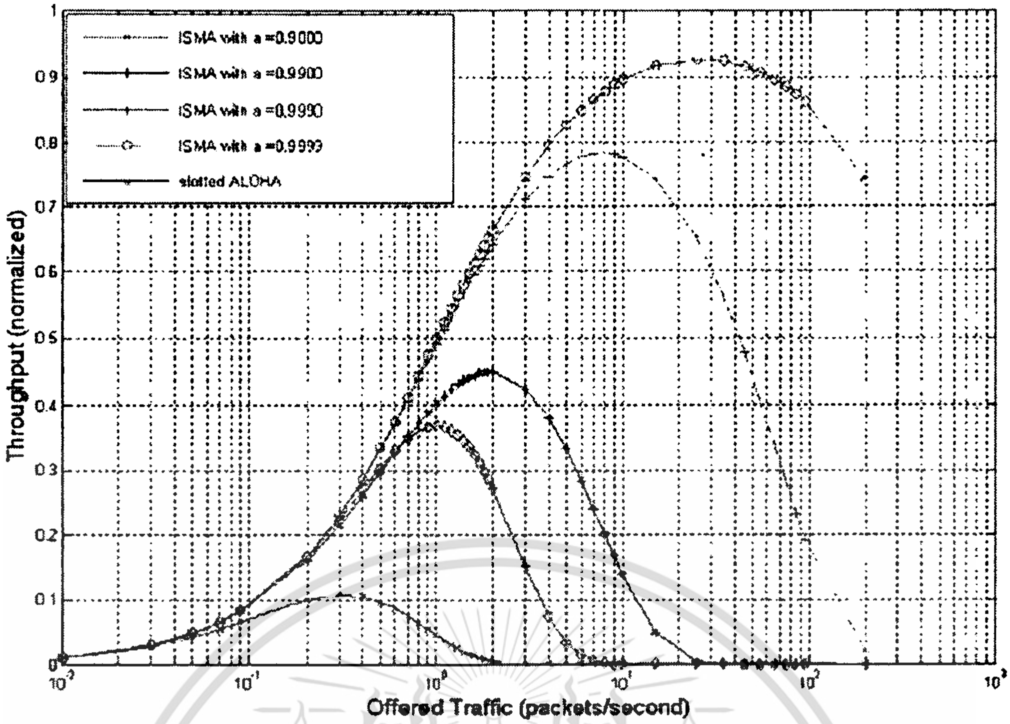

Figure 4.26c Throughput of modified slotted np-ISMA protocol and slotted ALOHA protocol with cover zone radius (r) = 700 km

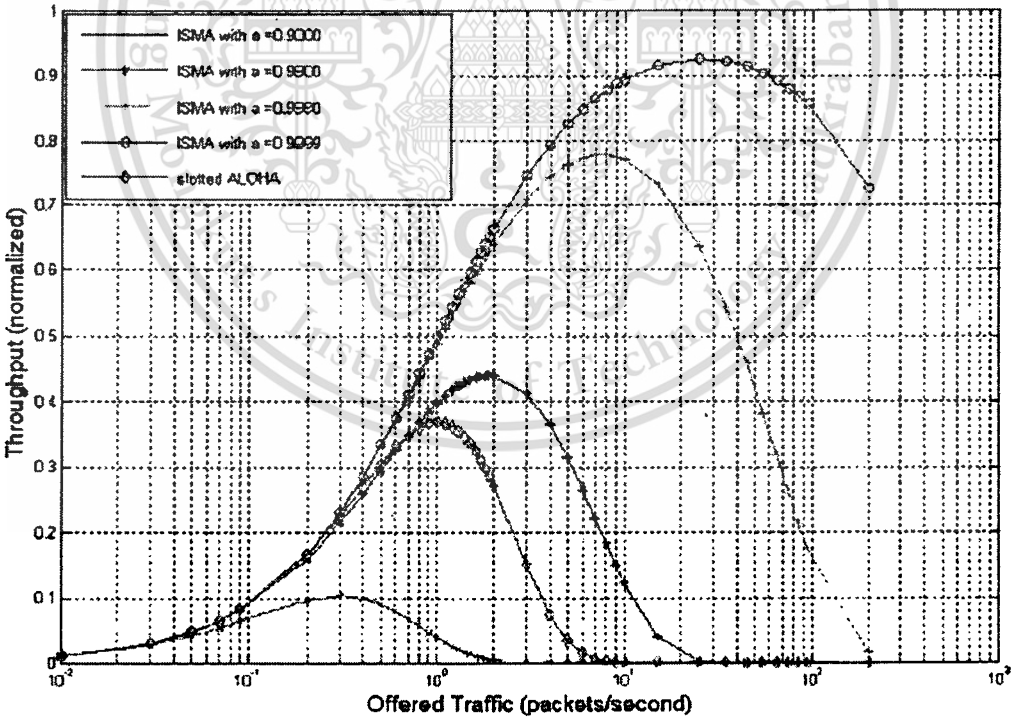

Figure 4.26d Throughput of modified slotted np-ISMA protocol and slotted ALOHA protocol with cover zone radius (r) = 1,000 km

4.4.2 Simulation results when varied the value of the packet length

Table 4.27 shows the conditions of the simulation with the values of the packet length (Mplen) are varied from 128 to 1,024 symbol.

Table 4.27 Simulation condition assumptions of the modified slotted np-ISMA protocol with the varying values of packet length (MPlen)

Symbol rate	Srate	256	ksymbol/second
Length of the packet	Mplen	128, 256, 512, 1,024 symbol	
Inhibited time (normalized)	d	0.001	-
Cover zone radius	r	100	km
High of the base station	z	1,000	km
Number of terminal	Mnum	300	-
Timing advance (% of Inhibited time)	a	90%, 99%, 99.9%, 99.99%	

Figures 4.27a, 4.27b, 4.27c and 4.27d show the relations between throughput and offered traffic of the modified slotted non persistent ISMA protocol and the slotted ALOHA protocol when the packet length Mplen = 128, 256, 512 and 1,024 symbol, respectively.

We can see in these figures that the throughput of the modified slotted non persistent ISMA protocol increases when the packet length decreases and the timing advance increases. And the throughput of the modified slotted non persistent ISMA protocol always higher then that of the slotted ALOHA protocol when the timing advance is over 99% of the inhibited time duration. We can see the simulation results summary on table 4.28.

Table 4.28 Maximum throughput of the modified slotted np-ISMA protocol with the varying values of packet length (MPlen)

Packet Length (MPlen) [symbol]	Maximum Throughput (normalized)			
	128	256	512	1,024
Slotted ALOHA	0.3679	0.3679	0.3679	0.3679
ISMA+90%	0.1874	0.2925	0.4154	0.5366
ISMA +99%	0.5751	0.6783	0.7629	0.8269
ISMA +99.9%	0.8430	0.8873	0.9196	0.9426
ISMA +99.99%	0.9485	0.9634	0.9741	0.9815

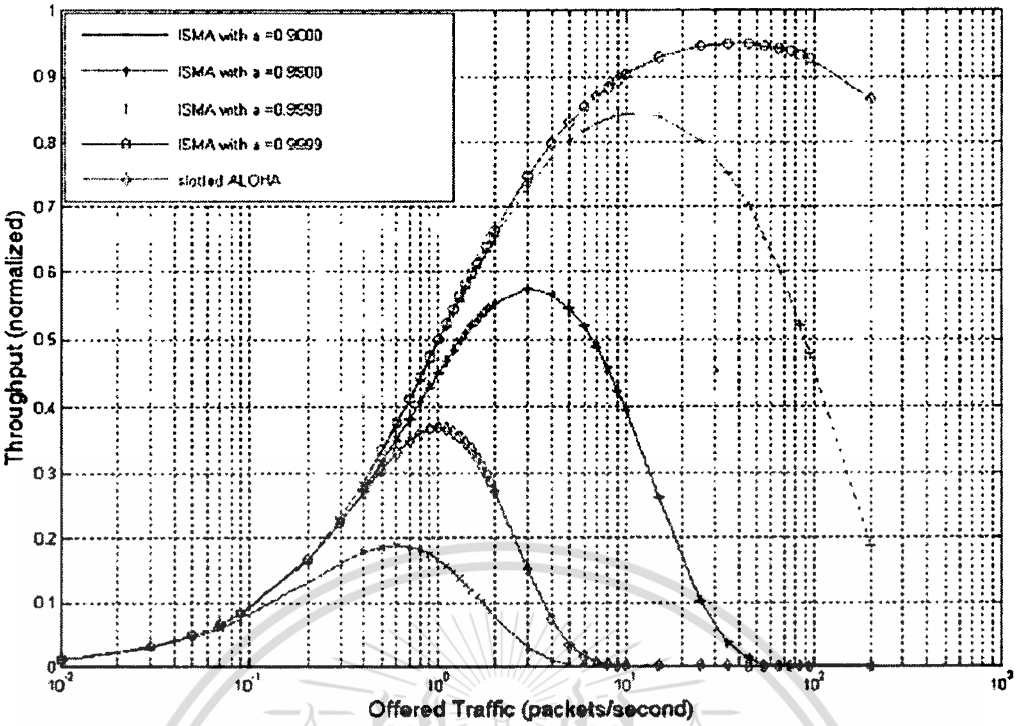

Figure 4.27a Throughput of modified slotted np-ISMA protocol and slotted ALOHA protocol with the packet length (Mplen) = 128 symbol

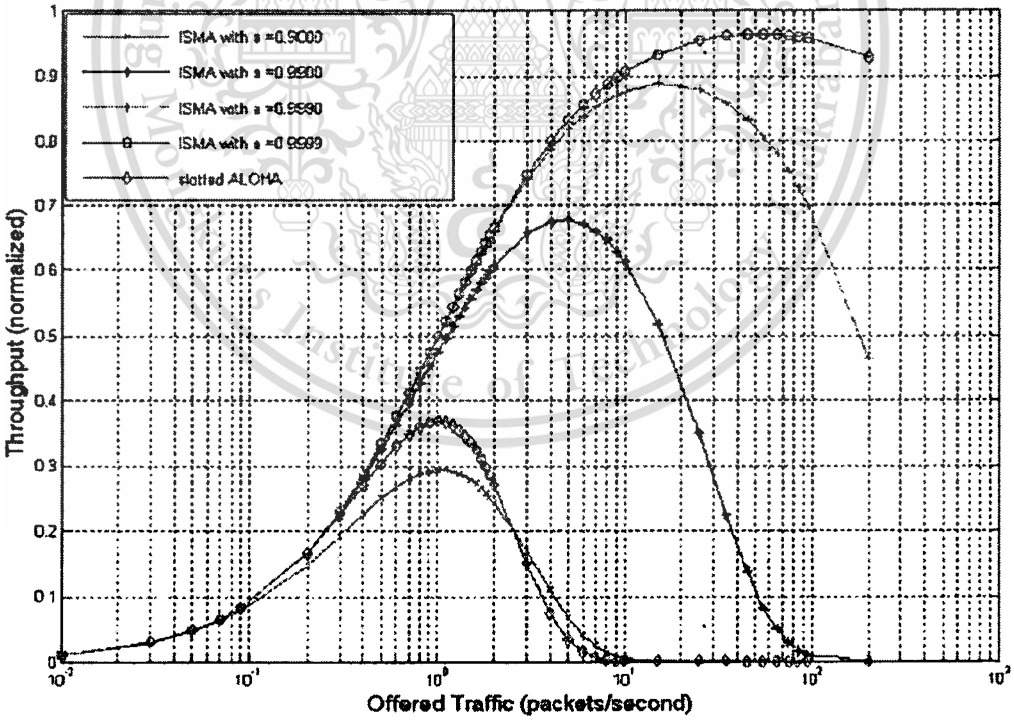

Figure 4.27b Throughput of modified slotted np-ISMA protocol and slotted ALOHA protocol with the packet length (Mplen) = 256 symbol

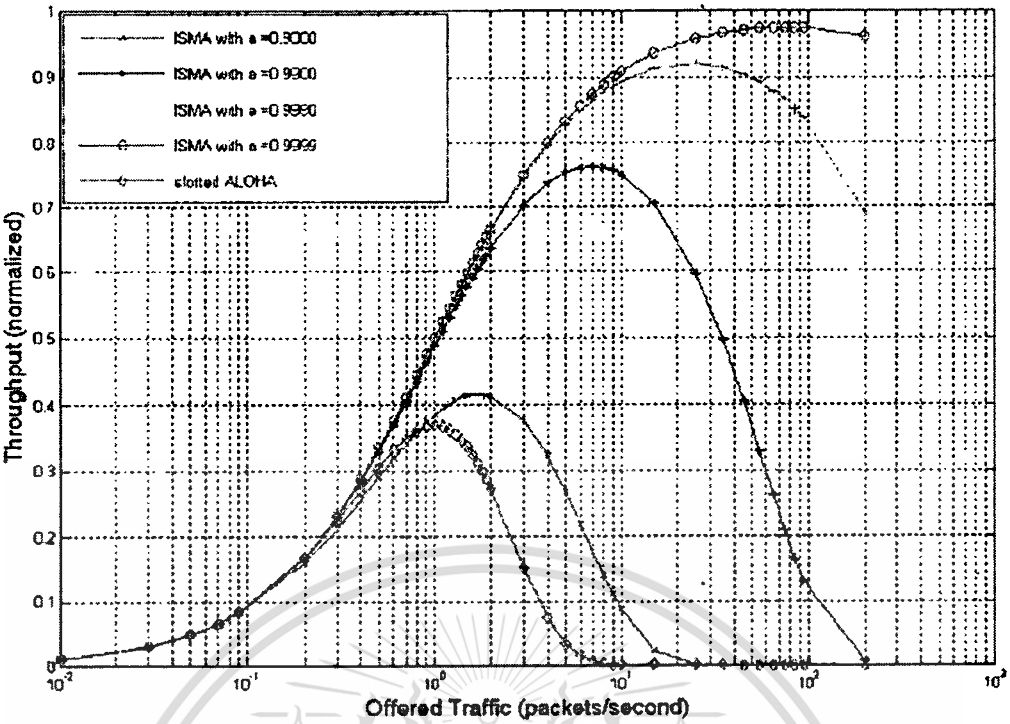

Figure 4.27c Throughput of modified slotted np-ISMA protocol and slotted ALOHA protocol with the packet length (Mplen) = 512 symbol

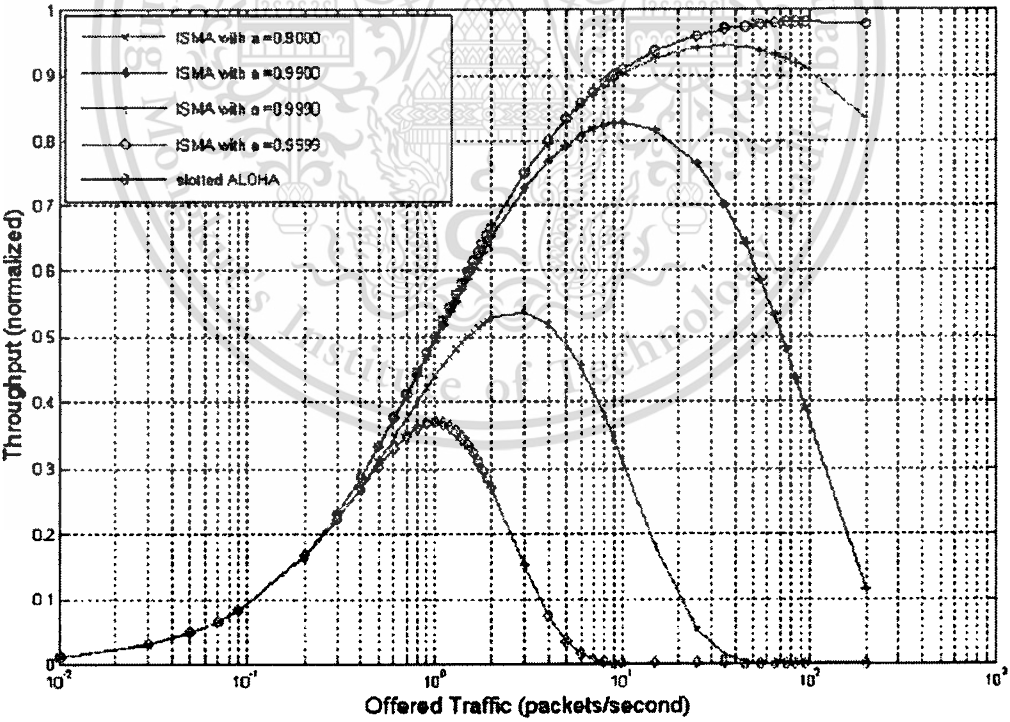

Figure 4.27d Throughput of modified slotted np-ISMA protocol and slotted ALOHA protocol with the packet length (Mplen) = 1,024 symbol

4.4.3 Simulation results when varied the value of the symbol rate

Table 4.29 shows the conditions of the simulation with the values of the symbol rate (Srate) are varied from 256 to 2,048 ksymbol/second.

Table 4.29 Simulation condition assumptions of the modified slotted np-ISMA protocol with the varying values of symbol rate (Srate)

Symbol rate	Srate	256, 512, 1,024, 2,048 ksymbol/second	
Length of the packet	Mplen	128	symbol
Inhibited time (normalized)	d	0.001	-
Cover zone radius	r	100	km
High of the base station	z	1,000	km
Number of terminal	Mnum	300	-
Timing advance (% of Inhibited time)	a	90%, 99%, 99.9%, 99.99%	

Figures 4.28a, 4.28b, 4.28c and 4.28d show the relations between throughput and offered traffic of the modified slotted non persistent ISMA protocol and the slotted ALOHA protocol when the symbol rate Srate =, 256, 512, 1,024 and 2,048 ksymbol/second, respectively.

We can see in these figures that the throughput of the modified slotted non persistent ISMA protocol increases when the symbol rate decreases and the timing advance increases. And the throughput of the modified slotted non persistent ISMA protocol always higher then that of the slotted ALOHA protocol when the timing advance is over 99% of the inhibited time duration. We can see the simulation results summary on table 4.30.

Table 4.30 Maximum throughput of the modified slotted np-ISMA protocol with the varying values of symbol rate (Srate)

Symbol Rate(Srate) [ksymbol/second]	Maximum Throughput (normalized)			
	256	512	1,024	2,048
Slotted ALOHA	0.3679	0.3679	0.3679	0.3679
ISMA+90%	0.4399	0.3160	0.2060	0.1227
ISMA +99%	0.7764	0.6971	0.5956	0.4780
ISMA +99.9%	0.9248	0.8937	0.8513	0.7928
ISMA +99.99%	0.9758	0.9658	0.9617	0.9321

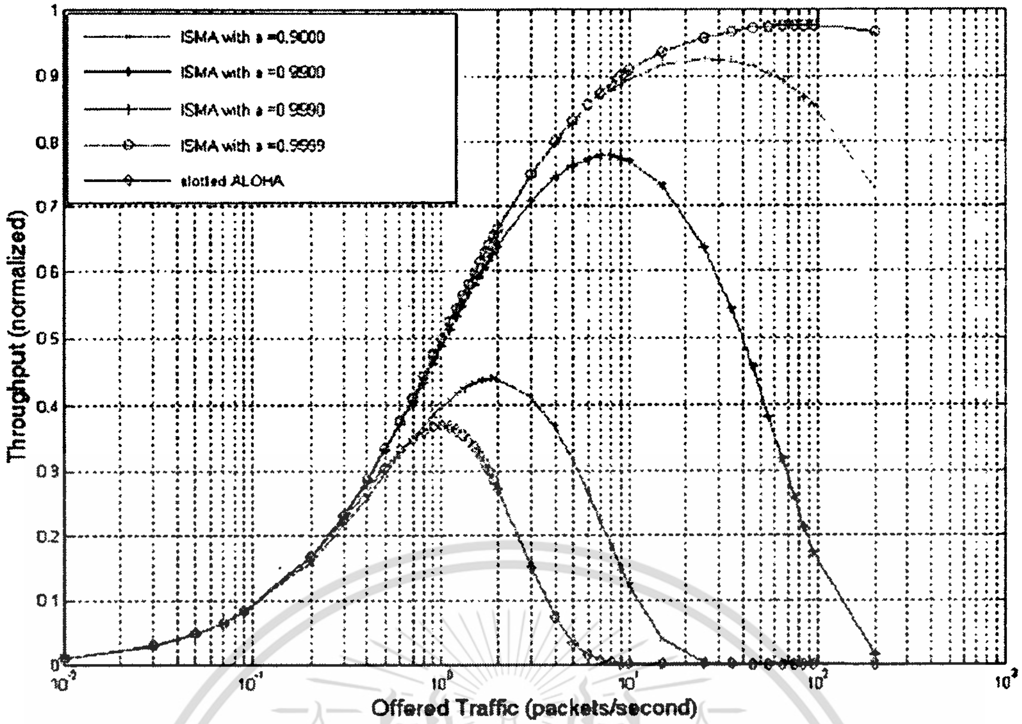

Figure 4.28a Throughput of modified slotted np-ISMA protocol and slotted ALOHA protocol with the symbol rate (Srate) = 256 ksymbol/s

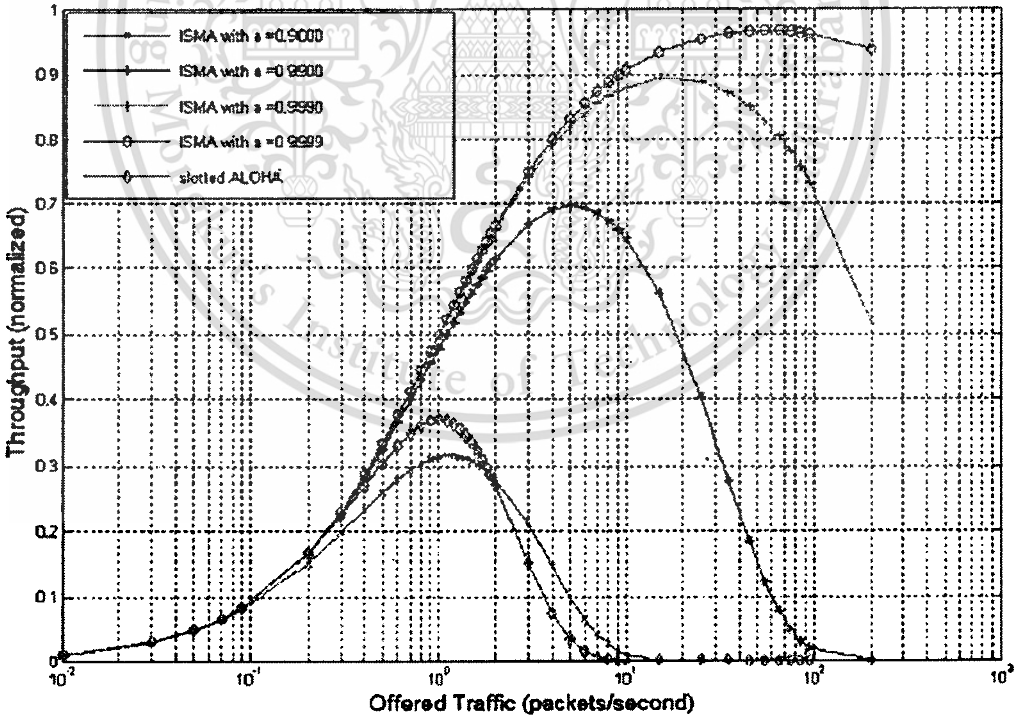

Figure 4.28b Throughput of modified slotted np-ISMA protocol and slotted ALOHA protocol with the symbol rate (Srate) = 512 ksymbol/s

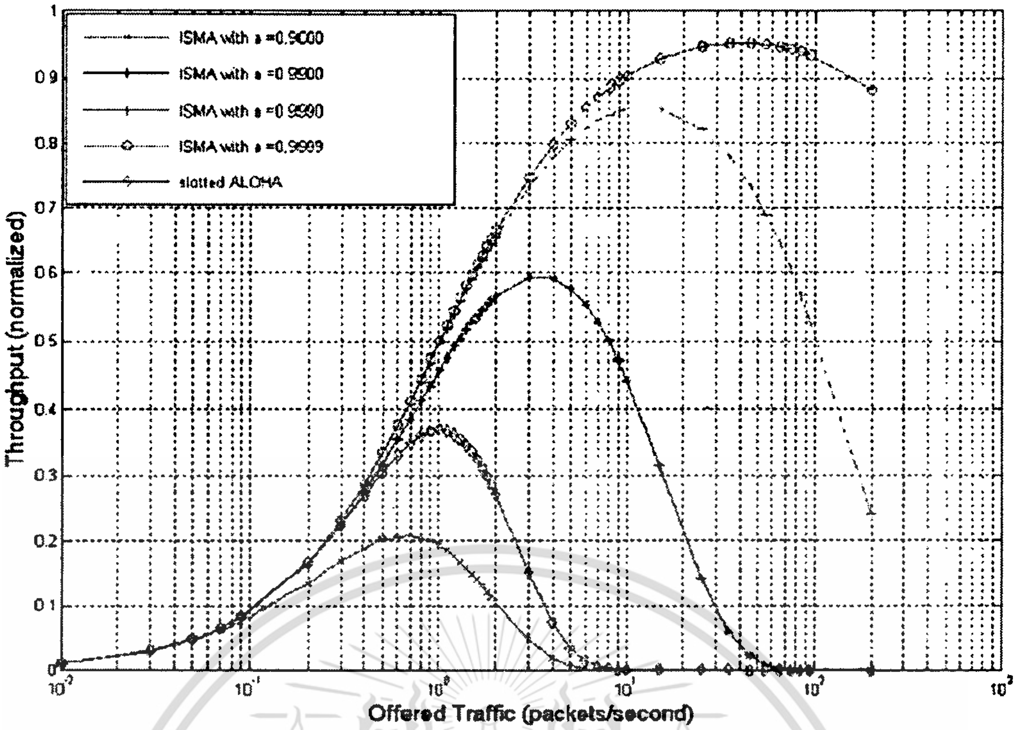

Figure 4.28c Throughput of modified slotted np-ISMA protocol and slotted ALOHA protocol with the symbol rate (Srate) = 1,024 ksymbol/s

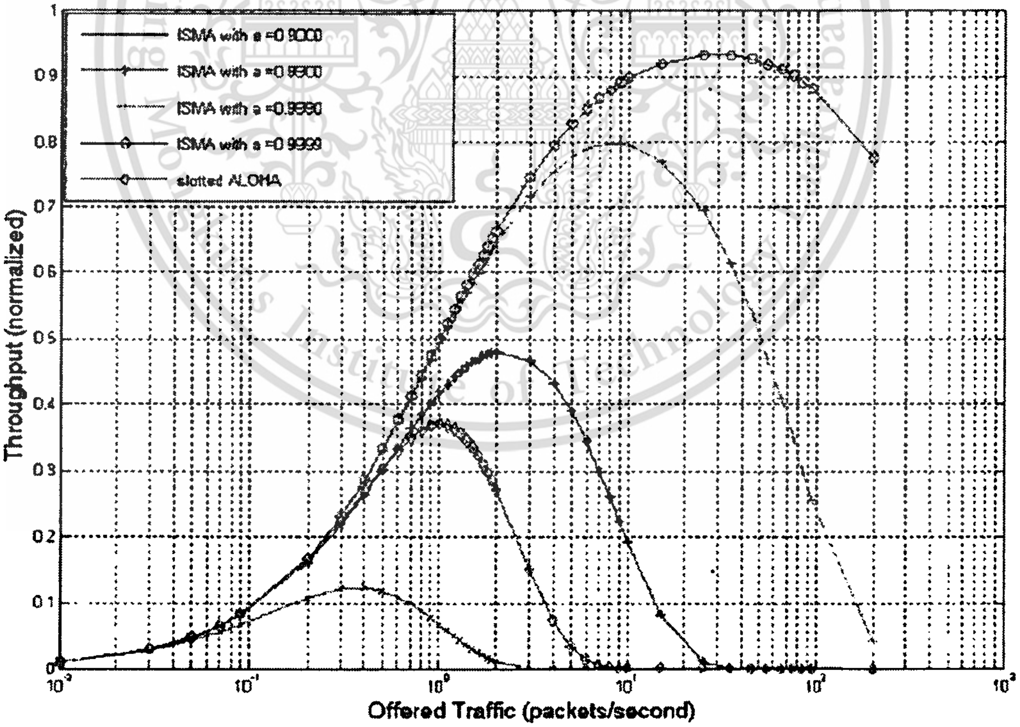

Figure 4.28d Throughput of modified slotted np-ISMA protocol and slotted ALOHA protocol with the symbol rate (Srate) = 2,048 ksymbol/s

4.4.4 Conclusions

From these simulations, we can see that the modified slotted non persistent ISMA protocol has the better performance than the slotted ALOHA protocol on the LEO packet satellite system when the timing advance a is over 99% of the inhibited time duration.

Further more, the modified slotted non persistent ISMA protocol can get the better performance on the LEO packet satellite when the cover zone radius decreases, the length of packet decreases and when the symbol rate decreases.

Chapter 5

CONCLUSIONS

Through all of the simulation results above, we can conclude that the modified slotted non persistent ISMA protocol has the better performance than the original slotted non persistent ISMA protocol and the slotted ALOHA protocol on the Low Earth Orbit (LEO) satellite system.

The performance of the modified slotted non persistent ISMA protocol will be increased when value of the timing advance factor is increased.

The performance of the modified slotted non persistent ISMA protocol will be increased when the service are radius is decreased. On this case, the throughput of system increases, the packet delay decreases, the collided attempt times and the inhibited attempt times also decrease, and the symbol rate is decreased.

The performance of the modified slotted non persistent ISMA protocol will be increased when the length of the packet is increased. On this case, the throughput of system increases, the packet delay increases, the collided attempt times and the inhibited attempt times decrease.

The performance of the modified slotted non persistent ISMA protocol will be increased when the symbol rate is decreased. On this case, the throughput of system increases, the packet delay increases, the collided attempt times and the inhibited attempt times decrease.

The modified slotted non persistent ISMA protocol has the better performance than the slotted ALOHA protocol on the LEO packet satellite system when the timing advance α is over 99% of the inhibited time duration.

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BIOGHRAPHY

Mr. **Tran Tuan Hung** was born in June 16th, 1977 at Hanoi, Vietnam. He received B. Eng in Faculty of Electronics and Telecommunications, Hanoi University of Technology, 1999. Since then, he has been a lecturer in the Faculty of Electronics and Telecommunications, Hanoi University of Technology. From May 2005 to May 2007, he is a master of engineering student of KMITL, Thailand, under the AUN/SEED-Net program.

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Page Number: 429 – 433

2. **Author's name:** Phichet Mongnoul, Tran Tuan Hung, Tawil Paungma.

Title of the paper: Investigation of Multi-Linear Chirp FH-CDMA over Fading Channel Model

Conference's name: 2005 Fifth International Conference on Information, Communication and Signal processing, ICICS2005, Bangkok, Thailand.

Page Number: 1480 - 1484

3. **Author's name:** Phichet Mongnoul, Tran Tuan Hung

Title of the paper: Throughput performance of modified Inhibit Sense Multiple Access protocol in packet satellite system.

Conference's name: IASTED Asian Conference on Communication Systems and Networks (AsiaCSN 2007), Phukhet, Thailand.