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A CROSS LAYERED APPROACH FOR SEAMLESS HANDOVER IN MOBILE WiMAX NETWORKS

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Abstract :WiMAX is a highly reliable and cost effective technology. A Mobile Mesh Network (MMN) involves communication between mobile nodes and mesh routers. Based on the Sponsor Node to adjacent node signal power Ratio (SNDR) value of each node, the decision for inter-cluster or intra-cluster handover is made. TCP Round Trip Timer (RTT) method is used to reduce congestion in the Base Station (BS) during handover. The congestion at the BS is detected and the contention window size is dynamically computed based on the contention RTT in the MAC layer and congestion RTT in the transport layer. The proposed system outperforms the existing system in terms of Throughput, delay, computation and message overheads.

Keywords: WiMAX, Handover, RTT, SNDR

Introduction

Worldwide Interoperability for Microwave Access (WiMAX) is a global technology. It is a part of the 4G wireless-communication technology which offers a Metropolitan Area Network (MAN) with a signal radius of about 50 km.

IEEE 802.16 is a series of wireless broadband standards written by the Institute of Electrical and Electronics Engineers (IEEE). Although the 802.16 family of standards is officially called Wireless MAN in IEEE, it has been commercialized under the name “WiMAX” by the WiMAX forum industry alliance.

WiMAX provides Broadband Wireless Access (BWA) upto 30 miles (50 km) for fixed stations and 3-10 miles (5-15 km) for Mobile Subscriber Stations (MSS). In contrast, the WiFi/802.11 wireless Local Area Network (LAN) standard is limited to only 100-300 feet (30-100m).

WiMAX operates on both licensed and non-licensed frequencies, providing a regulated environment and viable economic model for wireless carriers. It is a standard initiative which has an Internet Protocol (IP) based architecture which supports both Time Division Duplex (TDD) and Frequency Division Duplex (FDD) using multiple antenna techniques. It provides high speed broadband wireless access at a lower cost. It is indented to reach the remote places where the Digital Subscriber Line (DSL) and other cables do not reach.

WiMAX is also being touted as the solution for the “last mile problem” in high speed internet connectivity. The last mile costs are especially significant in rural areas, where the households are at a great distance from one another. Linking them together via cables can be time consuming and costly.

WiMAX operates similar to WiFi but at higher speed over greater distances and for a greater number of users. It has the ability to overcome the physical limitations of the traditional wired infrastructure and provide services even in areas that are not reachable with wired infrastructure.

The key feature of 802.16 is that it is a connection-oriented technology. The MSS cannot transmit data until it is allocated a channel by the BS. This allows mobile WiMAX (IEEE 802.16e) to provide better Quality of Service (QoS).

Types of WiMAX

There are 2 main types of WiMAX namely, Fixed WiMAX and Mobile WiMAX.

A. Fixed WiMAX

Broadband service and consumer usage of fixed WiMAX access is expected to reflect the fixed wire-line service with many standard based requirements being confined to the air interface.

WiMAX provides fixed, portable or mobile NLOS service from a BS to a MSS also known as Customer Premise Equipment (CPE). As communication takes place via wireless links from a WiMAX-CPE to a remote NLOS WiMAX BS, link security is highly demanded than a wireless service.

B. Mobile WiMAX

Mobile WiMAX takes the fixed wireless application a step further and enables cell phone-like applications on a much larger scale. For example, mobile WiMAX enables streaming video to be broadcast from a speeding police or other emergency vehicle at over 70 MPH. It potentially replaces cell phones and mobile data offerings from cell phone operators such as EvDo and HSDPA. In addition to being the final leg in a quadruple play, it offers superior building penetration and improved security measures over fixed WiMAX. Mobile WiMAX is very valuable for services such as mobile TV and gaming.

Layered Architecture

The 802.16 standard essentially standardizes two aspects of the air interface namely, the Physical layer (PHY) and the Media Access Control (MAC) layer. This section provides an overview of the technology employed in these two layers in the mobile 802.16e specification (Fig. 1).

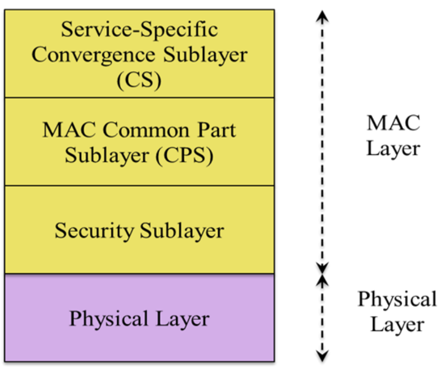

Figure 1. Layers in WiMAX

A. PHY Layer

The 802.16e uses Scalable Orthogonal Frequency Division Multiple Access (OFDMA) to carry data, supporting channel bandwidths between 1.25 MHz and 20 MHz, with up to 2048 sub-carriers. It supports Adaptive Modulation and Coding (AMC) so that in conditions of good signal, a highly efficient 64 Quadrature Amplitude Modeling (QAM) coding scheme can be used, whereas when the signal is poor, a more robust Bi-Polar (BPSK) coding mechanism can be used. Other PHY features include support for Multiple-In Multiple-Out (MIMO) antennas to provide good Non-Line-Of-Sight propagation (NLOS) characteristics or higher bandwidth and Hybrid Automatic Repeat Request (HARQ) for good error correction performance.

B. MAC Layer

The 802.16 MAC describes how wire line technologies such as Ethernet, Asynchronous Transfer Mode (ATM) and IP are encapsulated on the air interface and how data is classified. It also describes how secure communications are delivered by using secure key exchange during authentication and encryption using Advanced Encryption Standard (AES) or Data Encryption Standard (DES) during data transfer. Further, the MAC layer includes power saving mechanisms (using sleep mode and idle mode) and handover mechanisms. It includes three sublayers namely,

- Common Part Sublayer (CPS)
- Convergence Sublayer (CS)
- Security Sublayer

Common Part Sublayer (CPS)

The Common Part Sublayer (CPS) resides in the middle of the MAC layer. The CPS represents the core of the MAC protocol and is responsible for:

- Bandwidth allocation
- Connection establishment
- Maintenance of the connection between the two sides.

Convergence Sublayer (CS)

The service specific Convergence Sublayer (CS), often simply known as the CS is just above the MAC CPS sublayer. The CS uses the services provided by the MAC CPS, via the MAC Service Access Point (SAP). The CS performs the following functions:

- Accepting higher-layer PDUs from the higher layers.
- Classifying and mapping the MSDUs into appropriate Connection Identifier (CIDs).
- Processing the higher-layer PDUs based on the classification.
- Delivering CS PDUs to the appropriate MAC Service Access Point (MAC SAP) and receiving CS PDUs from the peer entity.
- Payload Header Suppression, an optional function of the CS is PHS.

Security Sublayer

The MAC Sublayer contains a separate Security Sublayer providing authentication, secure key exchange, encryption and integrity control across the BWA system. An authentication protocol, the Privacy Key Management (PKM) protocol is used to provide the secure distribution of keying data from the BS to the SS. Through this secure key exchange, due to the key management protocol the SS and the BS synchronize keying data. The basic privacy mechanisms are strengthened by adding digital-certificate-based SS authentication to the key management protocol.

Types of Services

The IEEE 802.16e MAC layer provides differential QoS for five classes of services- the Unsolicited Grant Service (UGS), Real-time services are classified into Extended Real-time Service (ertPS) and Real-time Service (rtPS) classes while Non-Real-time services are classified into Non-Real-time (nrtPS) and Best Effort (BE) classes.

- **UGS:** It is designed for Constant Bit Rate (CBR) real-time traffic such Voice over Internet Protocol (VoIP) without silence suppression. The main QoS parameters are the tolerated Jitter, Maximum Sustained Rate (MSR) and the Maximum latency.
- **ertPS:** It is designed to support VoIP with silence suppression. It has the same QoS parameters as UGS. However, MSR is assigned only during active periods.
- **rtPS:** It is designed to support real-time applications with variable bit rates, such as MPEG videos. The QoS parameters of rtPS services include MSR and Minimum Reserved Rate (MRR).
- **nrtPS:** It is designed for applications without any specific delay requirements but with minimum bandwidth requirements, such as a FTP.
- **BE:** It is designed for delay tolerant applications that do not require a minimum amount of bandwidth. Bandwidth is granted only after allocating to other service classes.

Handover

Handover takes place to provide continuous connection when a MSS migrates from an air interface of one BS to that of another BS. The WiMAX technology specifies a variety of handover schemes. When a MSS moves from one BS to another, the control information is transferred from the BS to which the MSS is currently linked, referred to as the home Base Station (hBS) to the BS under the range of which the MSS is to be connected, referred to as the target Base Station (tBS).

Based on connection establishment, handovers are classified into hard and soft handovers.

- **Hard handover:** The target cell can be gained only after the release of control from the home BS (hBS).
- **Soft handover:** The control of the target cell is gained in parallel when the MSS is in control of the home cell.

The handovers are classified into two types based on the movement of the MSS between Access Service Networks (ASN) as inter-ASN handover and intra-ASN handover.

- **Intra-ASN handover:** The MSS moves between different BSs belonging to the same ASN. The control information is directly transferred from the hBS to the tBS.
- **Inter-ASN handover**: The MSS moves between the BSs of different ASNs. The hBS is within the control of one ASN and the tBS is in the control of another ASN. The control information is transferred from the hBS to tBS through ASNs.

To reduce the Call Dropping Probability (CDP) and to increase the number of users, bandwidth should be dynamically allocated. To improve the latency for handover, a self-scanning with association scheme may be introduced. For each type of traffic, the available bandwidth, requested bandwidth and priority parameters are taken into account. Based on these parameters, the mobile that has the highest CDP will be given priority. The Arrival Rate (λ) is considered for and the performance of the proposed algorithm is measured.

The problem of congestion that occurs during the handover process is not considered in the existing system (ESP). TCP Round Trip Time (RTT) method is used to reduce the congestion in the network. If there is congestion, the number of packets sent from or to the BS is reduced.

Related Work

In [5], GPS is used to find the position of MS and the target BS is selected based on the distance. Another GPS based scanning mechanism that reduces the number of BSs scanned is proposed in [6].

A Multicast/Broadcast Service (MBS) architecture based on Location-Management Areas (LMAs), which increases the sizes of MBS zones, is presented in [7].

A Pre-Coordination Mechanism (PCM) for supporting fast handover in WiMAX networks is designed in [8]. The distance between the BS and the MS is measured and the time when the handover occurs is predicted, thus pre-allocating available resources for handover usages.

An agent based handoff scheme is proposed in [9], which improves the handoff process in mobile WiMAX networks using Enhanced Mobile Agents (EMA).

A MS - controlled fast MAC-layer handover (HO) scheme based on the Received Signal Strength (RSS) from any BS, that reduces the HO latency in Mobile WiMAX is proposed in [10].

Impact of handover on real time applications is investigated in [11]. Effective link layer triggering is done and signal strength is used as part of the trigger mechanism.

A linear regression model with predictive HHO algorithm that foresees the RSSI value and informs the MS to trigger the scanning procedure and handover process operations is discussed in [12].

The handover algorithm proposed in [13] relies on the computation of the received Signal-to-Noise Ratio (SNR) at a MS from neighbouring BSs, combined with the capacity estimation of the targeting cell.

Relative Signal Strength combined with Threshold, Hysteresis and Distance (RSTH-D) to initiate handover is presented in [14]. Distance is considered as a criterion to initiate fast handover.

A link-layer handover algorithm that enables an MS to receive downlink data before synchronization with uplink during handover process is proposed in [15]. A new management message is used to receive downlink data during the handover process.

A MAC Layer solution to guarantee the demanded bandwidth between two WiMAX end points during handover is presented in [16]. It also includes a scheme based on PHY and MAC layers to maintain the required communication channel quality for video streams during handover. The long interruption of hard handover in real-time applications like IPTV, VoIP and Sat TV is dealt in [17], The handover coordinator utilizes a network-based mobility management protocol as a basis to effectively and efficiently handle vertical handovers in a localized heterogeneous wireless environment.

Potential handover-related research issues in the existing and future WiMAX mobility framework is presented in [18]. IEEE 802.21, a new emerging standard aimed at providing a framework for media-independent handover (MIH) among heterogeneous networks is discussed. The authors propose a link-layer HO scheme called Passport Handover with a new Transport CID mapping strategy for real-time applications to avoid conflicts. Both uplink and downlink transmissions are completed before the handover process by prior reservation of resources.

The impact of HHO on speech quality in VoIP networks is evaluated in [19]. It proposes a handover Scheme with Geographic Mobility Awareness (HGMA), which considers the historical handover patterns of mobile devices

A handover scheme for real-time, delay sensitive applications is proposed in [20], in which the CID assignment strategy is used to avoid conflicting CIDs of handing over services with that of on-going services in the target BS. It also presents a proxy mobile IP based layer 3 handover scheme for mobile WiMAX based wireless mesh networks.

Some improvements at various stages of the handover, including the principle for selection of target BS depending on the type of traffic connection, managed by SS for real-time applications such as IPTV and VoIP ,is proposed and Seamless handovers within WiMAX and between WiMAX and WLAN is focused in [21].

In [22], the authors have proposed a velocity adaptive HO scheme to minimise handover delay and enhance the network resource utilisation. It proposes fast handover techniques between WiMAX and WiFi networks to speed up handover process in vehicular communications.

A MIH based Velocity Optimized Seamless Handover Mechanism (VOSHM) for WiMAX a network is described in [23]. It shows how the handover probability value is affected by the velocity of the mobile node. If an MT is associated with the WLAN for the longest possible duration, the user throughput is improved and even during the transition period, the RSS oscillates around the receiver sensitivity level [23].

A general framework for the vertical handover process based on fuzzy logic and neural networks is presented in [24].

The handover performance is measured from the viewpoint of the MAC or IP layer and physical layer. The handover performance affected by the radio channel quality, measured in terms of the Bit Error Rate (BER), and user's mobility in terms of the velocity by means of modelling the handover procedure are analysed.

The mobility improvement handover scheme that depends upon the velocity factor is considered in [25]. This scheme adjusts the handover and threshold handover RSS trigger values to improve the velocity of the MS. Policies considering different parameters like cost, power, available bandwidth and other parameters for different heterogeneous networks are analysed.

Existing System

In the existing system, the cluster head in a cluster is assigned a cluster ID and each node is assigned a node ID to distinguish between nodes in the cluster.

Cluster Formation and SNDR Calculation

Each Home Agent (HA) has a number of Foreign Agent (FAS) under it and each FA has a number of BSs under it. When the MSS sends the data to another MSS, it first goes to the BS. The BS forwards the data to the FA. The FA sends a response by forwarding the data to the HA. The HA verifies the identity of the MSSs. If the MSS' identity is verified, it sends the information about the MSS to the FA. The FA decides to which BS the data has to be forwarded. The BS then sends the data to the MSS. The decision with regard to either inter-cluster or intra-cluster handover is made depending on the measurement of the signal quality of SNDR and SCLR. Initially, a threshold is set for distinguishing handovers. SNDR determines whether the sponsor node should move within the same cluster or between clusters.

The SNDR value is calculated as follows.

$$\mathrm{SNDR} = \frac{E_i}{E_t} \qquad (1)$$

where,

E_i - Power of the received signal

E_t - Cross correlation between the signals

1. The cluster is formed with a FA, HA and BSs.
2. The FA and the HA verify the identity of the MSS and select the BS to which the data should be forwarded.
3. Scan for list of nodes.
4. For each sponsor node, a Sponsor-Node-to-adjacent-node signal power Ratio (SNDR) value is calculated. Based on this value, the decision to perform inter-cluster handover or the intra-cluster handover is made.
5. Initially, the threshold is set to distinguish between the inter-cluster and intra-cluster handover.
6. If the SNDR value is less than the threshold, the procedure for intra-cluster handover is carried out. Else, the inter-cluster handover procedure is carried out.

Handover Procedure

For each cluster, the SCLR value is calculated. Scanning for intra-cluster handover is given higher priority as it requires less handover overhead and less processing time in contrast to the inter-cluster handover.

The SCLR value can be calculated as follows.

$$\mathrm{SCLR} = \frac{E_c}{E_t} \qquad (2)$$

where,

E_c - Cross correlation between the received signals

E_t - Power of the received signal

"Procedure for Intra-Cluster Handover "

- The Serving-Cluster-to-adjacent-cluster signal power Ratio (SCLR) value is calculated for the serving cluster.
- A threshold is set for intra-cluster handover. If SCLR is greater than the threshold for the intra-cluster handover, scan for intra-cluster handover. Otherwise, begin with the inter-cluster handover procedure.
- In intra-cluster handover, compare the SNDRs of the nodes in the serving cluster to select a new candidate sponsor node.
- Select the sponsor node in the serving cluster with maximum SCLR.
- Scan for intra-cluster handover and select the node with the smallest number of hops from the cluster head.
- If the SNDR value of the sponsor node is less than the threshold, the procedure for intra-cluster handover is carried out. Else, repeat the previous step.

Procedure for Inter-Cluster Handover

- Scan for inter-cluster handover.
- Measuring the SNDRs of the nodes in the cluster with the maximum SCLR.
- Scan for inter-cluster handover and select the node with the smallest number of hops from the cluster head.
- If the SNDR value of the sponsor node is less than the threshold, the procedure for inter-cluster handover is carried out and network entry is done. Else, repeat the previous step.

RTT based Scheme (RTT_S)

In the proposed RTT based Scheme (RTT_S), the cluster formation and handover procedures are similar to those in the existing Preamble Design Technique (PDT).

The contention should be reduced. The contention delay (dc_i) is the time interval between the time the packet reaches the Head of the Queue (HoQ) and the time that the packet actually starts to be transmitted on the physical medium. This contention delay is unique for contention-based channel access schemes. It captures the fact that when a packet becomes the HoQ packet at node 'i', node 'i' may need to backoff before transmitting the packet on the physical medium. During node i's backoff time, if a neighbor transmits, then node 'i' must pause its backoff timer until this neighbor finishes its transmission. Therefore, the contention delay is related to the characteristics of the contention for the channel between neighboring nodes.

Reduction of contention using RTT

TCP Real Round-trip time (RTT) is divided into two parts:

1. Congestion RTT
2. Contention RTT

The Variance of Contention RTT per Hop (VCRH) gives the degree of link contentions. First, it represents the degree of link contention. Second, the variance is a random variable that reflects the contention observed during the recent observation window. The contention RTT is the sum of contention delays through the path which is a specific but essential factor in mobile networks.

On the other hand, the remaining part in RTT is the congestion RTT which is made up of the end-to-end transfer delay of all the links through the path.

Initially, the contention RTT is determined by forwarding packet. In the MAC agent, the contention delay is measured as the interval between a packet arrival at the head of line of the queue and the delivery time to the PHY layer. A time stamp is set in the fragment (frame) to keep track of the contention delay of the fragment in the current node. The contention delay is accumulated hop to hop and recorded in the fragment. Using the contention RTT and the congestion RTT, expectation (EXP) and variance (VCR)are calculated.

$$\mathrm{EXP_k} = \mathrm{EXP_{k-1}} \times (k-1) + \mathrm{CR_{new}} \quad (3)$$

$$\mathrm{VCR_k} = (\mathrm{VCR_{k-1}} + \mathrm{EXP_{k-1}^2}) \times (k-1) + \mathrm{CR_{new}^2} - \mathrm{EXP_k^2} \quad (4)$$

Using the values of mean and variance, VCR is calculated. VCRH is calculated by using VCR and number of hops as follows.

$$\mathrm{VCRH} = \frac{\mathrm{VCR}}{\mathrm{NUMBER\ OF\ HOPS}} \quad (5)$$

The VCR value is compared with the threshold. If the value is greater than the threshold, then congestion is more.

1. To reduce the congestion at the BS, TCP RTT method is used.
2. Using RTT, the delays in the MAC layer and transport layer are calculated, based on which, the mean and variance are calculated.
3. Based on the delay computed in the MAC and transport layers, the mean and variance are calculated and hence the Variance of Contention RTT (VCR) is calculated.
4. The Variance of Contention RTT per Hop (VCRH) is found. If the VCRH value is greater than the threshold set, then there are chances for congestion.
5. To reduce this congestion, the number of packets sent from BS is reduced or mobile node is switched to nearby BS.

Results and Discussion

This system is implemented using ns2. The simulation parameters are shown in Table 1.

Table 1: Simulation parameters

Parameters	Value
MAC	MAC/802.16
Packet size	512
Queue	DropTail/PriQueue
Routing	AODV
Contention Window size	32
Simulation time	80

If the number of messages in the BS is more, message overhead occurs and packet loss increases.

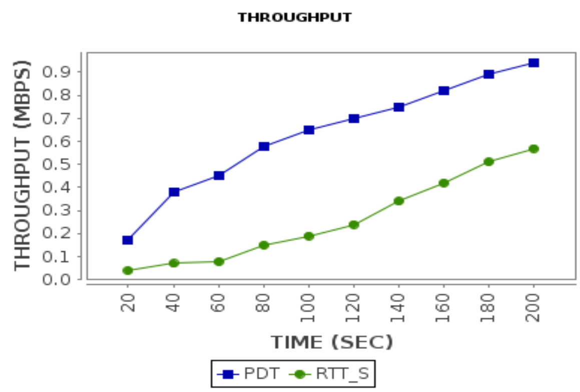

Figure 2. Throughput

Fig. 2 shows that the throughput in PESP is greater than ESP.

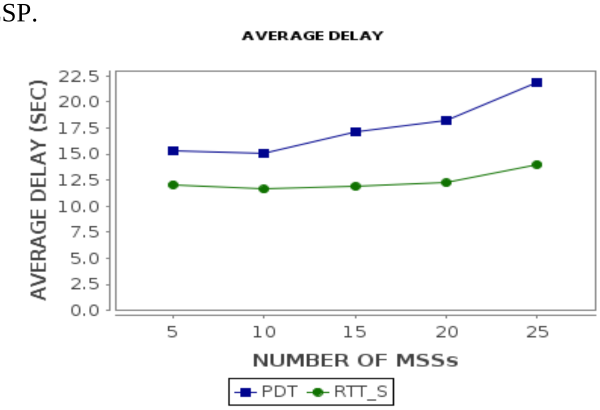

Figure 3. Delay

Fig. 3 shows that the delay in PESP is lesser than ESP.

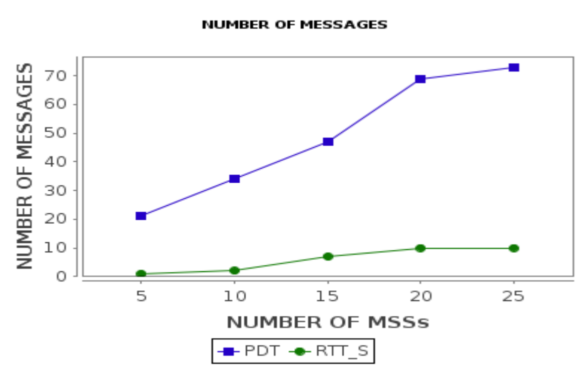

Figure 4. Number of messages

Fig. 4 shows that the number of messages in PESP is lesser than ESP.

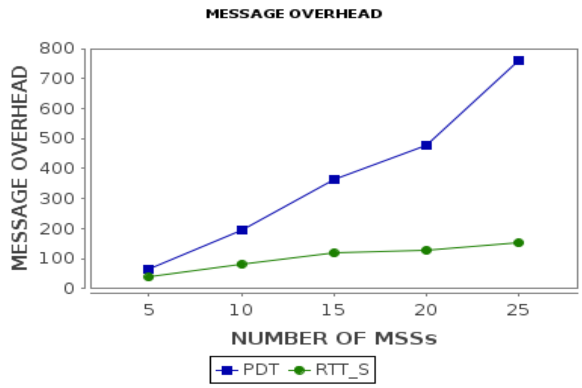

Figure 5. Message Overhead

Fig. 5 shows that the message overhead in PESP is lesser than ESP.

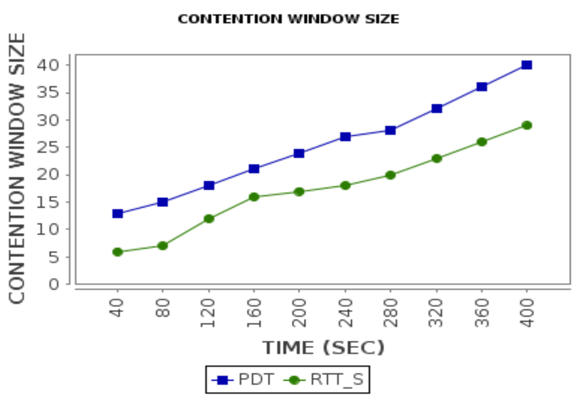

Figure 6. Contention Window

Fig. 6 shows that the contention window in PESP is greater than ESP.

Conclusion

The proposed system uses RTT to reduce congestion. The real RTT is split into congestion RTT and contention RTT. Through the deviation of the contention RTT and congestion RTT, the value of VCR is calculated. The new parameter VCRH is introduced to estimate the degree of contention in the network. Based on this value, the congestion that occurs in the network is reduced. The experimental results show that the proposed scheme yields better performance in terms of throughput, delay, message overhead, number of messages and contention window.

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