# DISTRIBUTED MULTI-HOP RESERVATION SCHEME FOR WIRELESS PERSONAL AREA ULTRA-WIDEBAND NETWORKS

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*To the loving memory of my Father and Mother and my Family*

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# ABSTRACT

Ultra-wideband (UWB) technology is a promising technology for multimedia applications in wireless personal area networks (WPANs) that supports very high data rates with lower power transmission for short range communication. The limitation of coverage radius of UWB network necessitates for multihop transmissions. Unfortunately, as the number of hops increases, the quality of service (QoS) degrades rapidly in multihop network. The main goal of this research is to develop and enhance multihop transmission that ensures QoS of real time traffic through the proposed distributed multihop reservation (DMR) scheme. The DMR scheme consists of two modules; distributed multihop reservation protocol (DMRP) and path selection. DMRP incorporates resource reservation, routing and connection setup that are extended on the existing WiMedia Media Access Control protocol (MAC). On the other hand, the path selection determines the optimal path that makes up the multihop route. The path selection selects nodes based on the highest Signal to Interference and Noise Ratio (SINR). The performance of DMR scheme has been verified based on the performance of the video traffic transmission. The main metrics of QoS are measured in terms of Peak Signal- to- Noise ratio (PSNR), End-to-End (E2E) delay, and throughput. The results show that DMRP compared to Multiple Resources Reservation Scheme (MRRS) in six (6) hops transmission has enhanced the average PSNR by 16.5%, reduced the average E2E delay by 14.9% and has increased the throughput by 11.1%. The DMR scheme which is the inclusion of path selection in DMRP has been compared to Link Quality Multihop Relay (LQMR). DMR scheme has improved the video quality transmission by 17.5%, reduced the average E2E delay by 18.6% and enhanced the average throughput by 20.3%. The QoS of six (6) hops transmission employing DMR scheme is almost sustained compared to two hops transmission with the QoS experiencing only slight degradation of about 2.0%. This is a considerable achievement as it is well known that as the number of hops increases the QoS in multihop transmission degrades very rapidly. Thus DMR scheme has shown to significantly improve the performance of real time traffic on UWB multihop network. In general, DMR can be applied to any WPAN network that exploit multihop transmission.

# ABSTRAK

Teknologi Jalur Lebar Ultra (UWB) adalah satu teknologi yang berpotensi untuk aplikasi multimedia dalam rangkaian kawasan peribadi wayarles (WPAN) yang menyokong kadar data yang sangat tinggi dengan kuasa transmisi yang lebih rendah berbanding untuk julat komunikasi yang lebih pendek. Pengehadan radius liputan rangkaian UWB diperlukan untuk penghantaran multihop. Malangnya, apabila bilangan hop meningkat, kualiti perkhidmatan (QoS) merosot dengan cepat dalam rangkaian multihop. Matlamat utama penyelidikan adalah untuk membangun dan meningkatkan penghantaran multi-hop yang memastikan QoS trafik masa nyata melalui skema tempahan multihop teragih (DMR) yang dicadangkan. Skema DMR terdiri daripada dua modul; Protokol Tempahan Multihop Teragih dan pemilihan laluan. *Distributed multihop Reservation Protocol* (DMRP) menggabungkan tempahan sumber, penghalaan dan persediaan sambungan yang diperluaskan pada protokol WiMedia *Medium Access Control* (MAC) sedia ada. Sebaliknya, pemilihan laluan menentukan laluan optimum yang membentuk laluan multihop. Pemilihan laluan memilih nod berdasarkan kuasa penghantaran tertinggi dan Nisbah Isyarat kepada Gangguan dan Hingar (SINR). Prestasi skema DMR telah disahkan berdasarkan prestasi penghantaran trafik video. Metrik utama QoS diukur dari segi Nisbah Isyarat Puncak kepada Hingar (PSNR), lengahan Hujung-ke-Hujung (E2E), dan truput. Keputusan menunjukkan bahawa DMRP telah dibandingkan dengan skema tempahan sumber multihop (MRRS) dalam penghantaran enam (6) hop telah meningkatkan PSNR purata sebanyak 16.5%, dengan mengurangkan lengahan E2E purata yang turun sebanyak 14.9% dan telah meningkatkan daya pemprosesan sebanyak 11.1%. Skema DMR iaitu pemasukan pemilihan laluan dalam DMRP telah dibandingkan dengan teknik sedia ada geganti multihop kualiti pautan (LQMR). Skema DMR telah meningkatkan penghantaran kualiti video sebanyak 17.5%, telah mengurangkan purata lengahan E2E iaitu sebanyak 18.6% dan telah meningkatkan purata truput iaitu sebanyak 20.3%. QoS bagi penghantaran enam (6) hop yang menggunakan skim DMR hampir berkekalan berbanding dengan penghantaran dua hop dengan QoS hanya mengalami sedikit kemerosotan sebanyak kira-kira 2.0%. Ini adalah peningkatan yang besar kerana ia diketahui bahawa bilangan hop meningkatkan QoS dalam penghantaran multihop merosot dengan cepat. Skema DMR telah menunjukkan peningkatan prestasi trafik masa nyata yang ketara pada rangkaian multihop UWB. Secara umum, DMR boleh digunakan untuk mana-mana rangkaian yang mengeksploitasikan penghantaran multihop.

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| | | |
|---|---|---|
| ACK | - | Acknowledgement |
| AVC | - | Advanced Video Coding |
| APP | - | Application Layer |
| B-ACK | - | Block- Acknowledgement |
| BER | - | Bit Error Rate |
| BP | - | Beacon Period |
| BS | - | Beacon Slots |
| BPST | - | Beacon Period Start Time |
| CAP | - | Contention Access Period |
| C-ARQ | - | Cooperative Automatic Repeat reQuest |
| CBR | - | Constant Bit Rate |
| CE | - | Consumer-Electronics |
| CF | - | Code-and-Forward |
| CIF | - | Common Intermediate Format |
| CSF | - | Channel Status Factor |
| CSMA | - | Carrier Sense Multiple Access |

| | | |
|---|---|---|
| CSMA/CA | - | Carrier Sense Multiple Access with Collision Avoidance |
| CTAP | - | Channel Time Allocation Period |
| DCF | - | Distributed Coordination Function |
| DCM | - | Dual Carrier Modulation |
| DevAddr | - | Device Address |
| DEX | - | Distributed Exclusive Region |
| DF | - | Decode-and-Forward |
| DLL | - | Data Link layers |
| D-MAC | - | Distributed Medium Access Control |
| DMRP | - | Distributed Multihop Reservation Protocol |
| DRP | - | Distributed Reservation Protocol |
| DR-MAC | - | Distributed Relay MAC |
| DTP | - | Data Transmission Period/ Data Transfer Period |
| E2E | - | End-To-End |
| ECMA | - | European Computer Manufacturers Association |
| EDCA | - | Enhanced Distributed Channel Access |
| GoP | - | Group of Pictures |
| GUI | - | Graphic User Interface |
| GWN | - | Gate Way Node |
| HDTV | - | High Definition Television |
| IE | - | Information Element |

| | | |
|---|---|---|
| IEEE | - | Institute of Electrical and Electronics Engineers |
| IP | - | Internet Protocol |
| IPTV | - | Internet Protocol Television |
| ITU | - | International Telecommunication Union |
| ISO | - | International Standard Organization |
| JVT | - | Joint Venture Team |
| LQMR | - | Link Quality Multihop Relay |
| MAC | - | Medium Access Control |
| MANET | - | Mobile Ad-Hoc Network |
| MA | - | Medium Access |
| MAS | - | Medium Access Slot |
| MRRS | - | Multihop Resource Reservation Scheme |
| MTU | - | Maximal Transmission Unit |
| MBOA | - | Multi Band OFDM Alliance |
| MB-OFDM | - | Multi-Band OFDM |
| MIB | - | Management Information Base |
| MIFS | - | Minimum Inter Frame Space |
| MIMO | - | Multiple In Multiple Out |
| MSDU | - | MAC Service Data Unit |
| MTU | - | Maximum Transmission Unit |
| MPEG | - | Moving Picture Experts Group |

| | | |
|---|---|---|
| MTCS | - | Multi-Path Transmission Control Scheme |
| NDT | - | Neighbor’s Data- rate Table |
| NED | - | Network Description |
| OFDM | - | Orthogonal Frequency Division Multiplexing |
| OSI | - | Open System Interconnection |
| P2P | - | Peer to Peer |
| PAPSF | - | Power Aware Path Status Factor |
| PCA | - | Prioritized Contention Access/ Prioritized Channel Access |
| PEF | - | Path Estimation Factor |
| PLCP | - | Physical Layer Convergence Protocol |
| PDU | - | Physical Layer Data Unit |
| PHY | - | Physical Layer |
| PMD | - | Physical Medium Dependent |
| PNC | - | Piconet Controller |
| PPDU | - | PLCP Protocol Data Units |
| PSDU | - | PLCP Service Data Units |
| PVR | - | Personal Video Recorder |
| PSNR | - | Peak Signal to Noise Ratio |
| QCIF | - | Quarter CIF |
| QoS | - | Quality of Service |
| QPSK | - | Quadrature Phase Shift Keying |

| | | |
|---|---|---|
| RA | - | Resource Allocation |
| RGB | - | Red Green Blue |
| RMSE | - | Root Mean Square Error |
| RNS | - | Relay Node Selection |
| RSSI | - | Received Strength Signal Indication |
| RTN | - | Relay Target Neighbors |
| RTP/ UDP | - | Real-time Transport Protocol/User Datagram Protocol |
| SAP | - | Service Access Point |
| SIFS | - | Short Inter Frame Space |
| SINR | - | Signal to Interference and Noise Ratio |
| SNR | - | Signal to Noise Ratio |
| SOP | - | Simultaneous Operating Piconet |
| TCP | - | Transmission Control Protocol |
| TDMA | - | Time Division Multiple Access |
| TIM | - | Traffic Identification Map |
| TMT | - | Theoretical Maximum Throughput |
| TV | - | Television |
| VBR | - | Variable Bit Rate |
| VTx | - | Video Traffic |
| UDP | - | User Datagram Protocol |
| UWB | - | Ultra-Wide Band |

| | | |
|---|---|---|
| WiMAX | - | Worldwide interoperability for Microwave Access |
| WLAN | - | Wireless Local Area Networks |
| WMN | - | Wireless Mesh Network |
| WPAN | - | Wireless Personal Area Network |
| WUSB | - | Wireless Universal Serial Bus |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Research Background

The enormous growth in popularity of wireless personal devices in Wireless Personal Area Network (WPAN) based on Ultra-wideband (UWB) (Zhang et al., 2017b) requires efficient communication technology. UWB is characterized by ubiquitous connections for security, household and military or medical applications due to the ability of providing low power consumption, small size, and inexpensive cost. The prominent features of UWB networks such as low power consumption, high-rate communications up to 0.5 Gbps, and low interference with other radio systems bring many benefits to users and enable several new applications such as the consumer-electronics in people's living rooms, high definition television (HDTV), and wireless universal serial bus (WUSB) to connect the personal computers to their peripherals (Heidari, 2008; Savazzi et al., 2013; Pushak et al., 2016) Medium Access Control (MAC) protocol design is one of the main challenges for High-Rate WPANs (Sindian et al., 2014). There are two major accessing techniques: contention-based and contention free (polling or reservation-based). MAC protocols can be designed in centralized or distributed approach.

An example of the centralized MAC approach is IEEE 802.15.3a protocol (IEEE std. 802.15.3, 2003) .The IEEE 802.15.3a MAC interconnects devices to form a piconet which consists of a piconet coordinator (PNC) and piconet member devices.

A PNC allocates channel resources to piconet member devices in its own piconet. However, the current IEEE 802.15.3a based on the centralized architecture has several problems. Firstly, if a PNC device disappears from the piconet, e.g., due to movement, dead battery, or channel condition, the member devices of the piconet waste lots of time and energy in order to re-elect a new PNC. As a result, the (QoS) of all streams cannot be guaranteed during the PNC re-election procedure. Secondly, when more than two piconets overlap each other, Simultaneous Operating Piconet (SOP) problem occurs causing significant degradation of the IEEE 802.15.3a. For example, if two devices connected to different PNCs are within the interfering range of each other and unfortunately use the same time slots, each device’s transmission will collide with the other, and therefore the performance of the piconet operation is deteriorated. Consequently, the centralized MAC approach in WPANs has critical problems in mobility support and QoS provisioning to real-time isochronous streams.

QoS imposes minimal requirements on bandwidth and latency. Within a Home Area Network (HAN), the video packet flow density may vary over time. High-definition Internet Protocol Television (IPTV) and Personal Video Recorder (PVR) services usually dynamically reserve certain time slot allocations over the channel, where these services will have exclusive access to the channel during their respective slots. As for IEEE 802.15.3a MAC, channel access is managed using Time-Division Multiplexing, where a centralized coordinated TDM coordinator decides the duration of the allocated time-slot for each device. This centralized approach may not be optimal for the following reasons:

- Normally, centralized schemes demand high communication and computational overheads. This overhead will be more significant in UWB networks due to their very high data rate. In addition, the traffic model for many applications targeted by UWB is bursty, such as video applications. Therefore, reserving sufficient channel resources for these applications would be challenging;

- Maintaining precise synchronization between network nodes and the coordinator is highly complicated and costly in large-scale networks, especially with the high UWB rates where bit durations are extremely small(Zhang et al., 2017b);
- Generally, centralized architectures are not easily scalable, and may suffer the single-point-of-failure problem (Daneshi et al., 2010) and;
- In a hierarchical network structure, where the network is divided into a group of small piconets, achieving coordination between these piconets is rather challenging. As a result, it is not easy to extend the coverage of WPANs with the current IEEE 802.15.3a (Chou et al., 2005; Lee et al., 2009; Espina et al., 2014).
- Consequently, the centralized MAC approach in WPANs has critical problems in mobility support and QoS provisioning to real-time isochronous streams, which leads to the introduction of a new distributed MAC.

The WiMedia is a distributed MAC (Alliance, 2009a), that offers exclusive access to the medium for the reservation owner in a fully distributed manner in a multi-hop UWB networks. In WiMedia MAC, the timeline is divided into fixed medium access slots (MAS) called superframe with duration of 65.536ms (Alliance, 2009a). One superframe has 256 MAS of 256 µs each in duration. MAS is the unit used for reservation. Each superframe has two main parts, a Beacon Period (BP) and a Data Transfer Period (DTP). During BP, the availability of information element (IE) is transmitted in a beacon which indicates a node's current knowledge about the utilization of all MASs. For Distributed Reservation Protocol (DRP) channel access, a sending node will observe the IE of all its neighbors, including the receiver, to find out in which MAS it could reserve for exclusive access. Unreserved MASs is available for contention-based access by all nodes with Prioritized Contention Access (PCA). Both of them have their pros and cons. For uplink transmissions in infrastructure based wireless networks and peer-to-peer communications in mesh or ad-hoc networks, resource reservation in DRP can ensure the QoS at the cost of lower resource utilization. For bursty video traffic with highest peak-to-average ratio, reservation leads to a significant waste of resources. Contention-based MAC protocols such as PCA are flexible and efficient in sharing resources by bursty traffic and they can achieve a certain level of multiplexing gain. However, their performance may degrade severely when the network is congested and collisions occur frequently. PCA allows High-Definition (HD) video transmission which are typically non-adaptive) over wireless networks (Zhang et al., 2010). With the state-of-the-art video coding technologies, the average data rates of HD video streams are decreasing (Zhang et al., 2010), but the burstiness and the peak-to-average ratio of the video streams become even higher. In addition, video applications such as IPTV have very stringent (QoS) requirements in terms of delay, jitter, and loss (Zhou et al., 2010). In this research, jitter matrix is beyond the scope and concentrating on the delay due to contention and hidden node problem. A critical and challenging issue for the success of video streaming over wireless networks is how to efficiently utilize the limited wireless resources to ensure the stringent QoS for video streaming applications.

As mentioned before, polling and reservation are two access strategies for contention-free MAC protocols. The reservation access strategy is more efficient and is often used to provide QoS guarantees for indoor distribution of high-definition IPTV and PVR services (Gnanavel and Ramakrishnan, 2017). Thus, this research mainly emphasizes on the distributed MAC protocols in WiMedia UWB.

## 1.2 Problem Statement

The primary challenge to enhance UWB network performance is to extend the network coverage and to ensure the QoS support in a multihop network (Joo and Hur, 2014). The research problems are further explained as below;

Current IEEE 802.15.3 MAC protocol for UWB is based on the centralized control (Zin and Hope, 2010). The centralized control allows two hops communication only. In order to allow more than two hops to extend the network transmission coverage, there should be distributed MAC protocol. The existing WiMedia MAC is a distributed protocol limited to two hops transmission with ensured system performance (Kim et al., 2010). Therefore, there is a need for enhancing the distributed MAC protocol to support multihop transmission.

Another problem with distributed MAC is that nodes can access the same media at their own decisions. So contention may happen due to nodes transmitting at the same time, thus causing packet collisions. In DRP, contention can be avoided by reserving time slots for nodes to transmit. However, contention avoidance is only limited to two hops. Therefore, for more than two hop communication, there is a need for a mechanism to overcome the contention (Hur et al., 2013).

In addition, the hidden node problem may cause packet loss due to collision. In a multihop network, the hidden node problem will cause some nodes to have smaller contention probability than others (nodes in hidden position). Therefore, different nodes will have different probabilities to gain the channel access, which can result in severe unfairness and overall performance incompetent (Alam et al., 2013). In DRP hidden node problem is avoided through request/response messages, however, this is limited to two hop transmissions only. Therefore, there is a need to minimize collision due to hidden node problem.

Furthermore, multihop transmission scenarios are not supported by DRP. To be able to transmit data to a node located more than one hop away from the source node, the current DRP protocol will require connection negotiations to be re-initiated for each hop along the path from the source node to the destination node. This entails a significant delay, especially if the path includes a large number of hops. Therefore, it is essential to develop a more efficient connection setup mechanism for multi-hop connection.

Finally, path selection in the current DRP mechanism is based on selecting the first node that responds to the source node request. This strategy manifests an obvious deficiency since the link quality between the source node and the selected node may be poor, whereas better link quality could exist with other nodes (Salarian, H., et al., 2014). Hence, it is reasonable to enhance the path selection strategy for better selection that results in a better link quality. This is specifically important in multihop scenarios, where one poor link impacts data transmission along the whole multihop path.

## 1.3 Research Objectives

The main goal of this research is to develop a distributed multihop transmission scheme for UWB network that ensures QoS requirement for real time communication. In order to achieve an effective multihop transmission the specific objective are:

- To develop a distributed reservation protocol that can support more than two hop transmissions.
- To enhance the performance of the distributed reservation protocol with path selection mechanism.

The distributed multihop reservation scheme will be developed based on WiMedia MAC protocol. The QoS requirements are measured in terms of Peak Signal to Noise Ratio (PSNR), throughput and End-to-End (E2E) delay. In this work, video traffic is assumed as the real time data transmission.

## 1.4 Research Scope

The MAC used in this work is based on WiMedia that supports two hop transmission for UWB networks. Since WiMedia allows distributed channel access it can be deployed for distributed reservation. In this work multihop transmission is assumed for more than two hops transmission.

Since multihop network involves the transmission over several paths, it is critical to select nodes that can determine the optimal route from the source to the final destination. Node selection is usually determined based on the link quality of the path. In this work the link quality is determined through the SINR.

The MAC protocol in the UWB network is assumed to use MB-OFDM, which allows high bit rate transmissions. Video transmission, which required high data rate can be transmitted on MB-OFDM. The video signal is assumed as the real-time signal. In this work the QoS of video as a real time signal depends on PSNR, throughput and overall E2E delay.

The proposed distributed multihop reservation scheme will be developed based on Wimedia model which will be formulated mathematically and later validated by extensive simulation study using Omnet++ simulator.

In this thesis, Distributed Multihop Reservation Scheme for UWB network is proposed. The method exploits Distributed Reservation Protocol (DRP) MAC and multi-hop technology (DMRP) to extend the network coverage, and path selection to improve the performance of UWB network. DMR scheme combined with UWB system can be an efficient solution to multihop network goals. DMRP using DRP is expected to improve multihop UWB network performance specifically against collision due to hidden node. The proposed DMR MAC for UWB network solves the major problems of the existing UWB network.

## 1.5 Research Contribution

In this work, the distributed multi-hop reservation scheme for UWB networks extends the network coverage and improves the network performance. The proposed distributed multi-hop reservation scheme for WPAN UWB networks comprises of modifying the Wimedia MAC protocol to extend transmission to more than two hops, selecting nodes for optimal path, reserving timeslot to avoid contention, and ensuring QoS of real-time data on multi-hop UWB networks. The main contributions of this research are as follows:

- **DMR**: The modification of Wimedia protocol to provide mutihop transmission and has been made and defined as DMRP. The algorithm involves the interaction between the UWB channel conditions at the physical layer (PHY) which affects the scheduling and resource allocation at the MAC layer and at the network layer, the multi-hop route selection. Unlike the traditional layered strategy, the proposed DMR algorithm is systematically developed to determine the path with the highest transmitted power and Signal to Interference and Noise Ratio (SINR) and multi-hop routing link/path selection. The scheme is carried out in a methodical way such that the interactions between the function layers are carefully linked, which leads to improving multi-hop transmissions without violation of the delay restrictions.
- **Path Selection**: For the second contribution, each device in the piconet should evaluate path estimation factor (PEF) which is calculated from SINR sent with the PHY header. The values of (PEF) are reported to PNC periodically. If two devices cannot communicate directly or there is a device can increase the total rate between sender and receiver. The proposed scheme uses the (PEF) to select the path with SINR is high.
- **DMRP:** The DMRP provides timeslot reservation at the intermediate node for multihop transmission. The DMRP Availability Information Element (IE) is created to send information the next hops on the slots being reserved on all the hops. The new protocol extends the coverage area by using the 2-hop DMRP

Availability IE. The DMRP schemes utilize decode and forward method to remove hidden node conflicts and to enhance the coverage radius, using the 2-hop DMRP Availability IE. The DMRP IE field included in the command frame corresponds to a reservation request identified by the target/owner device address, stream index, and the reservation type. Unlike the single hop, it acts as a current DRP reservation request, but for the Multi-hop level it acts as a DMRP reservation request. The DMRP reservation response command frame includes all the DMRP IEs from the reservation request. At the single hop, it acts as a conventional DRP reservation response, but for the Multi-hop level it acts as a DMRP reservation response.

The performance of DMR scheme has been investigated for data traffic and video traffic using Omnet++ simulator and the performance has been investigated based on PSNR, throughput, and E2E delay metrics.

## 1.6 Research Significance

The proposed DMR scheme is proven to be able to improve the performance of wireless transmission over multi-hop UWB network. This scheme works well with IEEE 802.15.3 distributed MAC. The proposed DMR scheme extends the UWB network coverage without increasing receiver sensitivity or transmitting power. With DMR scheme the throughput of the network is increased since the coverage radius is enhanced by using the DMRP Availability IE in Wimedia. The proposed DMR scheme ensures QoS support since it is a contention free channel access as it utilizes guaranteed MAS reservation. Furthermore, DMR selects the transmission path with highest SINR.

DMR in UWB network is well suited to users in business cores and high-density use in office buildings, wireless home networking, and WUSB. Moreover, since the proposed scheme is based on reservation approach, the scheme can also benefit other wireless network technologies such as worldwide interoperability for Microwave Access (WiMAX) and Wireless Local Area Networks (WLAN), but with parameter adjustments based on the respective wireless network technologies.

## 1.7 Research Outlines

The outline of the thesis which consists of six chapters has been arranged as follows;

Chapter 2 focuses on the latest progression in video coding technology, UWB technology, multi-hop networks, cross layer design and techniques related to multi-hop transmissions, The WiMedia MAC protocols especially DRP protocol. Also the chapter presented several design issues and related works in the DRP for video transmission over multi-hop UWB network. Moreover, the current DMRP approach in addressing tackling the problem of video transmission over multi-hop UWB network has been also analyzed and several gaps are identified to become the position for this research.

Chapter 3 primarily describes the proposed DMR scheme. It covers the basic design concept, the DMR network model and functional components. The flow chart diagram also outlined in this chapter and detailed description of the algorithm using block diagrams. In addition, the network simulations and configuration parameters used in the performance metrics and the process involved.

Chapter 4 presents the simulation study of video transmission over DMRP UWB network. Then the chapter evaluates its performance analysis of DMRP in terms of PSNR, Throughput, and E2E delay, and then compared with the existing DRP scheme.

Chapter 5 describes the development of path selection of the proposed DMR scheme. The distributed reservation protocol mechanism is integrated into DMRP to provide multihop transmissions over UWB networks. Then, the performance improvement generated by the DMR scheme in comparison to DMRP scheme and DRP scheme is presented. The performance metrics are in terms of evaluation PSNR, Throughput and E2E delay.

Finally, chapter 6 the thesis is concluded with a summary of the research along with perspective for future works.

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