RELAY SELECTION AND CONNECTIVITY IN MOBILE MULTIHOP RELAY NETWORK

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ABSTRACT

Mobile Multihop Relay (MMR) network is an attractive and low-cost solution for expanding service coverage and enhancing throughput of the conventional single hop network. However, mobility of Mobile Station (MS) in MMR network might lead to performance degradation in terms of Quality of Service (QoS). Selecting an appropriate Relay Station (RS) that can support data transmission for high mobility MS to enhance QoS is one of the challenges in MMR network. The main goal of the work is to develop and enhance relay selection mechanisms that can assure continuous connectivity while ensuring QoS in MMR network. The first approach is to develop and enhance a relay selection for MS with continuous connectivity in non-transparent relay. In this approach, the standard network entry procedure is modified to allow continuous connectivity with reduced signalling messages whenever MS joins RS that is out of Multihop Relay Base Station (MRBS) coverage and the relay selection is based on Signal to Noise Ratio (SNR). The second approach is to develop and enhance relay selection that allows cooperative data transmission in transparent relay that guarantees continuous connectivity. The proposed relay selection defined as Cooperative Relay Selection based on SNR and LET (Co-ReSL) depends on weightage of SNR, α and weightage of Link Expiration Time (LET), β. National Chiao Tung University network simulator (NCTUns) is used in the simulation study. The QoS performances of the proposed relay selections are in terms of throughput and average end-to-end (ETE) delay. The findings for the proposed relay selection in non-transparent relay shows that at heavy traffic load ρ=0.8, and MS speed of 30 m/s, throughput increases by 2.0% and average ETE delay reduces by 9.0% compared to random relay selection due to selection of RS with good link quality and provision of continuous connectivity. In addition, the throughput degradation between low mobility MS (30 m/s) and high mobility MS (50 m/s) is only about 2.0%. Findings for Co-ReSL show that at heavy traffic load, throughput increases up to 5.7% and average ETE delay reduces by 7.5% compared to Movement Aware Greedy Forwarding (MAGF) due to cooperative data transmission in selective links. By setting α=0.8 for Co-ReSL, the decrement of throughput between low mobility MS and high mobility MS is about 2.3% compared to the rapid decrement of 5.5% and 6.0% experienced by Co-ReSL with α=0.2 and MAGF, respectively. In addition, Co-ReSL improves throughput by 11.9% and reduces average ETE delay by 7.7% compared to non-cooperative method. The proposed relay selection mechanisms can be applied in any high mobility multi-tier cellular network.

ABSTRAK

Rangkaian Pengulang Banyak-lompatan Bergerak (MMR) adalah penyelesaian menarik dan rendah kos untuk memperluaskan liputan perkhidmatan dan meningkatkan kadar penghantaran data rangkaian tanpa wayar lompatan tunggal konvensional. Walau bagaimanapun, mobiliti Stesen Bergerak (MS) dalam rangkaian MMR mungkin menyebabkan penurunan prestasi dari segi Kualiti Perkhidmatan (QoS). Salah satu cabaran dalam rangkaian MMR adalah pemilihan Stesen Pengulang (RS) yang sesuai yang boleh menyokong penghantaran data untuk mobiliti MS yang tinggi bagi meningkatkan QoS. Matlamat utama kerja ini adalah untuk membangunkan mekanisme pemilihan pengulang yang boleh memberi jaminan sambungan berterusan di samping memastikan QoS dalam rangkaian MMR. Pendekatan pertama adalah untuk membangunkan satu mekanisme pemilihan pengulang untuk MS dengan sambungan berterusan dalam pengulang tidak telus. Dalam pendekatan ini, prosedur kemasukan rangkaian standard diubah suai untuk membenarkan sambungan berterusan dengan mengurangkan isyarat mesej bila-bila masa MS menyertai RS yang berada di luar liputan Stesen Pangkalan Pengulang Banyak-lompatan (MRBS). Pemilihan pengulang adalah berdasarkan kepada Nisbah Isyarat kepada Gangguan (SNR). Pendekatan kedua adalah untuk membangunkan pemilihan pengulang yang membolehkan penghantaran data secara kerjasama dalam pengulang telus yang menjamin sambungan berterusan. Pemilihan pengulang yang dicadangkan didefinisikan sebagai Pemilihan Relay secara Kerjasama berdasarkan SNR dan LET (Co-ReSL) bergantung kepada pemberatan SNR, α dan pemberatan Masa Sambungan Tamat (LET), β. Simulasi rangkaian Universiti Kebangsaan Chiao Tung (NCTUns) digunakan dalam kajian simulasi. Prestasi QoS bagi pemilihan pengulang yang dicadangkan adalah kadar celus dan purata kelewatan hujung-ke-hujung (ETE). Hasil kajian pemilihan pengulang yang dicadangkan dalam pengulang tidak telus menunjukkan bahawa pada beban trafik $\rho=0.8$ dan kelajuan MS 30 m/s, kadar celus meningkat sebanyak 2.0% dan purata kelewatan ETE berkurang sebanyak 9.0% berbanding dengan pemilihan RS dengan kualiti pautan yang baik dan peruntukan sambungan berterusan. Tambahan pula, kemerosotan kadar celus antara mobiliti MS rendah (30 m/s) dan mobility MS tinggi (50 m/s) hanya kira-kira 2.0%. Hasil kajian Co-ReSL menunjukkan bahawa pada beban trafik berat, kadar celus meningkat sehingga 5.7% dan purata kelewatan ETE berkurang sebanyak 7.5% berbanding dengan Pemajuan Tamak Peka Gerakan (MAGF) disebabkan oleh penghantaran data secara kerjasama dalam pautan terpilih. Dengan menetapkan $\alpha=0.8$ untuk Co-ReSL, kadar celus antara mobiliti rendah MS dan mobiliti tinggi MS susut kira-kira 2.3% berbanding dengan susutan yang cepat sebanyak 5.5% dan 6.0% yang dialami oleh Co-ReSL dengan $\alpha=0.2$ dan MAGF, masing-masing. Co-ReSL meningkatkan kadar celus sebanyak 11.9% dan mengurangkan purata kelewatan ETE sebanyak 7.7% berbanding dengan kaedah tidak kerjasama. Mekanisme pemilihan pengulang yang dicadangkan boleh digunakan dalam mana-mana rangkaian selular pelbagai peringkat yang bermobiliti tinggi.

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LIST OF ABBREVIATIONS

AF	-	Amplify-and-Forward
AMC	-	Adaptive Modulation and Coding
AN	-	Active Node
AODV	-	Ad-hoc On-demand Distance Vector
API	-	Application Programming Interface
ARP	-	Address Resolution Protocol
BE	-	Best Effort
BS	-	Base Station
BWA	-	Broadband Wireless Access
CBR	-	Constant Bit Rate
CDMA	-	Code Division Multiple Access
CID	-	Connection Identification
CLD	-	Cross Layer Design
CM	-	Channel Model
Co-ReSL	-	Cooperative Relay Selection based on SNR and LET
CR	-	Cognitive Radio
DCD	-	Downlink Channel Descriptor
DF	-	Decode-and-Forward
DL	-	Downlink
DL-MAP	-	Downlink map
DT-FWD	-	Data Forwarding
ertPS	-	extended real-time Polling Service
ETE	-	End to End
FIFO	-	First In First Out
FRS	-	Fixed RS
FTP	-	File Transfer Protocol

GPS	-	Global Positioning System
GUI	-	Graphical user interface
HTTP	-	Hypertext Transfer Protocol
IMT	-	International Mobile Telecommunications
IP	-	Internet Protocol
IR	-	Initial Ranging
ITS	-	Intelligent Transport System
LAN	-	Local Area Network
LET	-	Link Expiration Time
LOS	-	Line of Sight
LTE	-	Long Term Evaluation
MAC	-	Medium Access Control
MAGF	-	Movement Aware Greedy Forwarding
MANET	-	Mobile Ad-hoc Network
MCN	-	Multihop Cellular Network
MCS	-	Modulation and Coding Scheme
MMR	-	Mobile Multihop Relay
MRBS	-	Multihop Relay Base Station
MRS	-	Mobile Relay Station
MS	-	Mobile Station
MSID	-	Mobile Station Identity
NLOS	-	Non Line of Sight
NRS	-	Nomadic RS
nrtPS	-	non-real-time Polling Service
PHY	-	Physical
PKM-REQ	-	Privacy Key Management Request
PKM-RSP	-	Privacy Key Management Response
QAM	-	Quadrature amplitude modulation
QoS	-	Quality of Service
QPSK	-	Quadrature Phase Shift Keying
REG-RSP	-	Registration Response
REP-SYNC	-	Reply Synchronization
REQ-SYNC	-	Request Synchronization

ReSL	-	Relay Selection based on SNR and LET
RNG-REQ	-	Ranging Request
RNG-RSP	-	Ranging Response
RS	-	Relay Station
rtPS	-	real time Polling Service
SBC-REQ	-	Subscriber station basic capability request
SBC-RSP	-	Subscriber station basic capability respond
SNR	-	Signal to Noise Ratio
SS	-	Subscriber Station
SSH	-	Secure Shell
STA-ACK	-	Station Acknowledgement
STA-INFO	-	station information
TCP/IP	-	Transmission Control Protocol/ Internet Protocol
UCD	-	Uplink Channel Descriptor
UDP/IP	-	User Datagram Protocol/Internet Protocol
UGS	-	Unsolicited Grant Service
UL	-	Uplink
UL-MAP	-	Uplink map
VoIP	-	Voice over Internet Protocol
WiMAX	-	Worldwide Interoperability of Microwave Access
WSN	-	Wireless Sensor Network

LIST OF SYMBOLS

r_{max}	-	Maximum transmission range
σ	-	Instantaneous received SNR
σ_n	-	SNR threshold
N	-	Number of transmission modes supported by MMR network
r	-	Transmission range
v_i	-	Speed of node i
(x_i, y_i)	-	Coordinates of node i
θ_i	-	Movement direction angels for node i
a	-	Relative velocity of the receiver node with respect to the sender node along Y-axis
b	-	Distance of the receiver node from the sender node along X-axis
c	-	Relative velocity of receiver node with respect to the sender node along Y-axis
d	-	Distance of the receiver node from the sender node along Y-axis
μ	-	Service rate
λ	-	Arrival rate
σ_{RS_i}	-	Received SNR from MS to the RS
σ_{AMC}	-	SNR threshold from AMC table
W_s	-	Weight of BS-MS
W_r	-	Weight of MS-RS
W_p	-	Weight of RS-BS
N_{OFDMA}	-	Number of OFDMA symbols per slots
N_{subc}	-	Number of subcarriers per slot

CR	-	Coding rate
mod	-	Modulated symbol
F_d	-	Frame duration
P_{loss}	-	Packet loss rate
P_{tx}	-	Total number of packet transmitted from the source node
P_{rx}	-	Total number or packets received at the destination node
$Delay_{ETE}$	-	Average end-to-end delay
$time\_rx_i$	-	Time packet i received at the destination node
$time\_tx_i$	-	Time packet i transmit from the source node
N_p	-	Total number of packets being transmitted
τ	-	Throughput
t_N	-	Time needed for the last packet N arrive at the destination node
t_i	-	Time for the time required for the first packet i send from the source node
L_q	-	Average number of packets in the queue
ρ	-	Traffic load of the node
L	-	Average number of packets in the system
wT_q	-	Average waiting time in the queue
wT	-	Average waiting time in the system
W_i	-	Weighted score
α	-	Weight of SNR
β	-	Weight of LET
LET_S	-	Supply LET
LET_D	-	LET demanded by the network
l_i	-	Current locations of node i
l_i'	-	Nodes i's locations after t time units
(x_i', y_i')	-	Nodes i's coordinate after t time units
$dist_i'$	-	Distance of nodes i and b based on node i moving speed

$v_i^{'}$	-	Nodes i's velocity after t time units
t_0	-	Start time
$t^{'}$	-	Time after moving
MS_i	-	Current MS
RS_i	-	Neighbor RS
RS_{list}	-	List of RS_i
C_{list}	-	List of candidate RS_i
P_{list}	-	List of potential RS_i
P_j	-	Sorted potential RS_i
P_r	-	Received power
P_t	-	Transmit power
G_r	-	Antenna gain at receiver
G_t	-	Antenna gain at transmitter
G_t	-	Path loss
G_t	-	SNR value between $MS_i$and RS_iLink
N_f	-	Noise figure
N_0	-	Thermal noise level
B	-	Effective channel bandwidth
F_s	-	Frequency sampling
N_{used}	-	Number of data subscriber
N_{FFT}	-	FFT size
LET_i	-	LET value between $MS_i$and RS_iLink
$Nexthop$	-	Selected next hop to forward data packets
J_n	-	Number of potential RSs
$P_{SR_i}^{j_R}$	-	Minimum transmit power of source-R_i
$P_{R_iD}^{j_D}$	-	Minimum transmit power of R_i-destination
j_R	-	Corresponding channels of source-to-relay link
j_D	-	Corresponding channels of relay to destination link
I_{SB}	-	Interference from source to destination
I_{R_iB}	-	Interference from R_i to destination
I_T	-	Interference threshold of base station

R_i	-	Optimal relay
k	-	Number of cooperative relaying
P_m	-	Data packet
rTable	-	Routing table

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CHAPTER 1

INTRODUCTION

1.1 Background

Rapid growth in number of mobile connected devices such as smart phones and tablets leads to the demand for high capacity network with high data rate and QoS provisioning for multimedia applications. In order to meet these requirements, next-generation cellular network needs to extend network capacity and coverage. Under limited frequency resources, the conventional approach to enhance network capacity is by installing more MRBS to exploit spatial reuse. However, this is not an efficient solution because the cost to install MRBS is high. An alternative approach to reduce the cost is to employ low cost RS in assisting data transmission between MRBS and MS in MMR network [1], [2].

MMR has emerged as a potential technology for data transmission in cellular mobile network. MMR network can provide high data rate and thus capacity enhancement, coverage extension and mobility support. It is low cost network deployment and provides QoS improvement for multiple types of applications [3], [4]. In MMR network, multihop RS is introduced to assist data transmission between MRBS and MS when single hop link quality is not good.

The concept of MMR network is similar to traditional Multihop Cellular Network (MCN). In this network, MS with good link quality can directly communicate with MRBS while MS with poor link quality, especially the ones located at the cell edges, communicates with MRBS via RS. RSs provide multiple links to be used for data transmission from MS to MRBS and vice versa. Efficient relay selection techniques are required to determine reliable links among the available links based on system parameters such as link quality[5], [6], traffic load [7] and radio resource availability [8].

As mentioned earlier, MSs located at cell edges receives very low signal strength from MRBS, which lead to higher probability of link failures. Moreover, node mobility is an additional factor that causes link failure to occur frequently in the network. Link failure between nodes degrade network performance severely [9]. Multihop relaying is a renowned technique that supports frequent change of network topology [10]. Hence, exploiting multihop relaying technology and equip it with awareness towards varying link stability due to node mobility is essential in order to enhance network performance [11].

In mobile communication, MS may suffer from performance degradation due to the time varying channel condition. This leads to limitation of the data rate and network QoS. Cooperative transmission may enhance network performance by using multiple RSs in assisting data transmission between MRBS and MS. Whenever a link is broken due to bad link condition or node mobility, other RSs that provide better connection to the MS can be chosen. Thus, the average end-to-end (ETE) delay and throughput can be improved. Cooperative communication has been considered as an efficient solution in multihop relaying [12]–[14] because it provides higher throughput, robustness for time varying channel [15], [16], space diversity gain, and enable users to transmit data at high speed and with high reliability.

1.2 Problem Statement

The main issue for MS in MMR network is performance degradation due to node mobility. When MS moves, it needs to change network or roams from the current RS to another RS. Additional delay is introduced each time MS intends to attach to another RS which causes the average ETE delay to increase. If the coverage range of RS is large, the duration of nodes staying connected is high, so the frequency to change network is reduced and vice versa. However, in practical, coverage range of RS is not as large as MRBS coverage due to its smaller transmission power. Therefore, there is a need for a mechanism to choose an appropriate RS effectively whenever MS moves out of current network coverage to maintain continuous connectivity and hence high throughput for the MS [17], [18].

It is clearly understood in the literature that multihop relaying extends network coverage area and enhances network capacity [19], [20], [21]. However, as MS moves from one point to another point, the performance is degraded due to random variation of channel and network condition [22], [23]. Therefore, proper selection of RS to overcome the performance degradation problem during data transmission is one of the challenging tasks in MMR network.

Usage of RS provides multiple communication links between MRBS and MS. Each communication link may have different characteristics. Due to the path loss and shadowing experienced for each communication link [7], [8], [24], link quality, channel condition, traffic load and radio resource availability are affected. Therefore, there is a need to select the potential communication link that meets QoS requirements.

The demand for multimedia service with higher data rate leads to requirement of high network capacity in next generation cellular network. Traditional approach to overcome network capacity requirement by installing more MRBS to support QoS guarantee for multiple types of applications [3], [4] is costly for MRBS installation is expensive, thus, RS is used since it offers a cost effective solution with lower complexity. However, the usage of RSs incurs higher delay and may degrade multimedia throughput due to multihopping transmission. Thus, there must be a proper relay links usage that can minimize delay and enhance throughput.

1.3 Objectives of the Research

The main goal of this work is to develop relay selection mechanisms to enhance mobility support and QoS performance of MS in MMR network. Two types of RS operation modes have been considered in this work namely non-transparent and transparent relay modes. The specific objectives of the thesis include:

i) To develop and enhance relay selection mechanism with continuous connectivity for MSs in non-transparent MMR network.

ii) To develop and enhance relay selection that ensures continuous connectivity in transparent MMR network through cooperative data transmissions.

The QoS performance metrics considered in this work are throughput and average ETE delay of MSs in the MMR network. Relay selection mechanisms in both transparent and non-transparent relay network will be dealt separately to overcome the different issues encountered in each network.

1.4 Scope of the Research

In this work the MMR network is assumed to operate up to two hops. The MSs are assumed moving and the changing speed may vary up to 50m/s (180 km/h). The proposed relay selection mechanisms with continuous connectivity to enhance QoS performance in MMR network have been developed for transparent and non-transparent relay mode. The work can be divided into three main focus issues:

i) In the non-transparent mode the coverage range is enhanced through continuous connectivity for MSs in MMR network. As the MS moves outside the coverage range of current RS, it can continue to be connected to other RS through the proposed connectivity procedure directly linked to the relay without incurring the repetition of the network procedure.

ii) Second, effective relay selection mechanism is developed for MS in MMR network. Additionally, link quality information is used to choose the suitable modulation type and coding rate based on Modulation and Coding (MCS) scheme for data transmission. Implementation of the modulation type and coding rate with the highest number of bits per symbol is expected to increase the data rate, and thus enhance throughput in MMR network.

iii) Finally, cooperative and relay selection mechanism is developed to further enhance the network performance in terms of throughput and delay.

In this work, NCTUns simulation tool is used to measure the network performance in MMR network because NCTUns supports the IEEE 802.16j standardization.

1.5 Research Contributions

The proposed relay selection mechanism enhances QoS performance of MSs in MMR network through continuous connectivity, relay selection mechanism and cooperative relay transmission. The significance contributions achieved from this research work are as follows:

i) Support of continuous connectivity for MS in non-transparent relay mode – During data transmission MS is allowed to move out of MRBS coverage range and yet continues to be connected to the network through other relay stations through a connectivity procedure without having to perform lengthy network entry procedures. The proposed connectivity procedure reduces signalling overhead.

ii) Relay selection mechanisms that decide based on link quality and link stability – The relay selections have significantly enhanced MS throughput and minimizes MS ETE delay of high mobility MSs in MMR network.