ENHANCED DISTRIBUTED MOBILITY MANAGEMENT SCHEME FOR IP-WSN BASED ON SENSOR PROXY MIPV6

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LIST OF ABBREVIATIONS

AAA	Authentication, Authorization and Accounting
ABRO	Anchor Based Route Optimization
AP	Access Point
AR	Access Router
BCE	Binding Cache Entry
BLT	Buffer Life Time
BU	Binding Update
BUL	Binding Update List
CMM	Centralized Mobility Management
CBA	Correspondent Binding Acknowledgement
CBU	Correspondent Binding Update
CN	Corresponding Node
CoA	Care of Address
DAD	Duplicate Address Detection
DFPMIPv6	Distributed Fast Handoff Proxy Mobile IPv6
DMAG	Dynamic Mobile Access Gateway
DMM	Distributed Mobility Management
DPBA	Distributed PBA
DPBA	Distributed PBA
DPBU	Distributed PBU
DSPMIPv6	Distributed SPMIPv6
F-DMM	Fully Distributed Mobility Management
FFD	Fully Function Device
FMIPv6	Fast MIPv6
GW	Gateway
HA	Home Agent
HM	Handoff Imminent
HMAG	Head MAG
HMIPv6	Hierarchical MIPv6
HNP	Home Network Prefix
HoA	Home of Address
IA	Intermediate Anchors
IETF	Internet Engineering Task Force

IMA	Local Mobility Anchor
IoT	Internet of Things
IP	Internet Protocol
IPv6	Internet Protocol version 6
LGD	Link Going Down
LIRO	LMA Initiated RO
LMA	Local Mobility Anchor
LMAA	LMA Address
LoWPAN	Low Power over Personal Area Network
LPBA	Local PBA
LPBU	Local PBU
LRA	Localized Routing Acknowledgment
LRI	Localized Routing Initiation
MAG	Mobile Access Gateway
MAP	Mobile Anchor Point
MIH	Media Independent Handover
MIPv6	Mobile IPv6
MN	Mobile Node
MN-ID	MN Identifier
MNN	Mobile Network Node
MNP	Mobile Network Prefix
MR	Mobile Router
NAM	Network Animation
ND	Neighbor Discovery
NETLMM	Network-Based Localized Mobility Management
NEMO	Network Mobility
NIST	National Institute of Standards and Technology
NS2	Network Simulator 2
Omnet++	Objective Modular Network Testbed in C++
PAN	Personal Area Network
PBA	Proxy Binding Acknowledgment
PBQ	Proxy Binding Query
PBU	Proxy Binding Update
PCoA	Proxy CoA
P-DMAG	Previous-DMAG
P-DMM	Partially Distributed Mobility

PMIPv6	Proxy MIPv6
PQA	Proxy Query Acknowledgment
RA	Router Advertising
RF	Forwarding Request
RFD	Reduced Function Device
RO	Route Optimization
ROT	RO Trigger
RS	Router Solicitation
RSS	Received Signal Strength
S-DMAG	Serving-DMAG
SLMA	Sensor LMA
SMAG	Sensor MAG
SMR	Session-to-Mobility Ratio
SNEMO	Sensor NEMO
SPMIPv6	Sensor PMIPv6
TCL	Tool Command Language
WSN	Wireless Sensor Network

LIST OF SYMBOLS

$T_{x\text{-}y}$	Transmission cost of a packet between nodes x and y
P_C	Processing cost of node C for binding update or lookup
T_{setup}	Setup time for connecting MN with MAG
N_{DG}	Number of DMAGs in PMIPv6 domain
N_{MN}	Number of active hosts per DMAG
$C_{DMAG\text{-}SLMA}$	Hop count between nodes DMAG and SLMA
$C_{MN,CN\text{-}DMAG}$	Hop count between nodes MN or CN and DMAG
$C_{DMAG\text{-}DMAG}$	Hop count between two DMAGs
S_{Ctrl}	Size of a control packet (byte)
S_{Data}	Size of data packet (byte)
α	Unit cost of binding update with SLMA
β	Unit cost of lookup for DMAG
pDMAG	Previous Dynamic Mobile Access Gateway
sDMAG	Serving Dynamic Mobile Access Gateway
ηcn	Average number of CNs during handover
τ	Unit transmission cost of packet per a wired link (hop)
κ	Unit transmission cost of packet per a wireless link (hop)
p_h	Probability of handover traffic
P_n	Probability of new traffic
T_{BCE}	Binding cache entry life time
N_{cn}	Number of CNs
N_{MN}	Number of active MNs
χ	IPv6 tunnel header size

PERTINGKATAN SKIM PENGURUSAN MOBILITI TERAGIH UNTUK IP-WSN BERDASARKAN PROKSI PENDERIA MIPv6

ABSTRAK

Protokol pengurusan mobiliti sangat penting dalam bidang penyelidikan baru Internet untuk Segala (IoT). Ini adalah disebabkan oleh hakikat bahawa sifat-sifat statik nod tidak lagi dominan dalam aplikasi semasa dan yang baru muncul. Rangkaian Penderia Tanpa Wayar berasaskan-IP (IP-WSNs) memberi potensi besar, dan bertujuan untuk mengesan dan mencari Node Mudah Alih (MN) dengan cekap untuk memberi pengguna akses penuh kepada maklumat tanpa mengira lokasi mereka. Penderia Proksi Mudah Alih IPv6 (SPMIPv6), adalah penyesuaian protokol asas berdasarkan rangkaian PMIPv6 yang dikenali sebagai Pengurusan Mobiliti Berpusat (CMM). Kelemahan skim CMM, seperti pembolehan skala, laluan yang tidak optimum, dan titik kegagalan tunggal, membawa kepada pembangunan skim Pengurusan Mobiliti Teragih (DMM). Matlamat tesis ini adalah: pertama, untuk mereka bentuk seni bina yang dipertingkatkan untuk SPMIPv6 yang dipanggil pendekatan SPMIPv6 Teragih; penyelesaian ini bertujuan untuk memisahkan entiti-entiti kawalan dan satah data. Tugas Penambat Mobiliti Tempatan Penderia (SLMA) adalah terhad kepada mengekalkan operasi pengurusan Kache Mengikat. Gerbang Akses Mudah Alih Dinamik (DMAG) diperkayakan dengan fungsi penambat mobiliti dengan satu set unik awalan global, mengekalkan suatu Kache Mengikat Tempatan (LBC) untuk MN yang dilampirkan kepadanya untuk membolehkan penghantaran dan penguraian mesej kawalan untuk mengemas kini sesi mobiliti, bertindak sebagai penghala biasa data yang disediakan dengan pautan ke Internet, dan tidak menawarkan dasar terowong untuk menghantar paket ke dan dari Internet yang tidak menyiratkan laluan-laluan yang melintas melalui SLMA. Kedua, ia adalah untuk meningkatkan penyerahan segera berdasarkan seni bina DSPMIPv6 untuk mengurangkan kos isyarat penyerahan dan saiz paket tercicir yang dipanggil Proksi Pantas Teragih MIPv6 (DSPMIPv6). Ketiga, untuk membangunkan skema Pengoptimuman Laluan (RO) yang baru yang dikenali sebagai Pengoptimuman Laluan Teragih (DRO), yang menyediakan pemulihan cepat status RO selepas penyerahan MN menggunakan kos isyarat penyerahan yang rendah. Keputusan berangka dan simulasi menggunakan simulator Omnet++, membuktikan bahawa DSPMIPv6 yang dicadangkan mengatasi prestasi kedua-duanya PMIPv6 dan SPMIPv6 dari segi beban SLMA sebanyak 54% dan 56% , Kos Isyarat sebanyak 28% dan 25%, kependaman penyerahan sebanyak 69% dan 61% dan penangguhan hujung ke hujung sebanyak 45% dan 65%. Keputusan simulasi membuktikan bahawa skim DFPMIPv6 yang dicadangkan mengatasi prestasi PMIPv6, MFPMIPv6 dan HFPMIPv6 dari segi kependaman penyerahan masing-masing sebanyak 47%, 56% dan 52%, pada waktu yang sama menjamin saiz paket tercicir sebanyak 79% berbanding dengan PMIPv6 asas. Penggunaan DMAG mempunyai impak yang baik terhadap prestasi keseluruhan. Ini disebabkan oleh penyediaan skim penampan yang hampir dengan DMAG yang berkomunikasi dan mengurangkan kependaman penyerahan. Akhir sekali DRO yang baru menyediakan pemulihan pantas status RO selepas penyerahan MN menggunakan kos isyarat penyerahan yang rendah. Keputusan simulasi membuktikan

bahawa skim DRO yang dicadangkan melebihi kerja sebelum ini dari segi kelewatan pautan berwayar; jumlah kos telah dikurangkan sebanyak lebih kurang 28% dan 38% dan jumlah kos dikurangkan sebanyak 71% dan 77% berbanding dengan yang dari LIRO dan ABRO, masing-masing.

ENHANCED DISTRIBUTED MOBILITY MANAGEMENT SCHEME FOR IP-WSN BASED ON SENSOR PROXY MIPV6

ABSTRACT

Mobility management protocols are very essential in the new research area of Internet of Things (IoT). This is mainly due to the fact that the static attributes of nodes are no longer dominant in the current and emerging applications. IP-based Wireless Sensor Networks (IP-WSNs) provide a tremendous potential, and aim to track and locate Mobile Nodes (MNs) efficiently to provide the user with full access to information irrespective of their locations. Sensor Proxy Mobile IPv6 (SPMIPv6), is an adaptation of the network based basic PMIPv6 protocol known as Centralized Mobility Management (CMM). The drawbacks of the CMM scheme, such as scalability, non-optimal routes, and single points of failure, led to the development of a Distributed Mobility Management (DMM) scheme. The goals of this thesis are: firstly, to design an enhanced architecture for SPMIPv6 called the Distributed SPMIPv6 approach; this solution aimed to de-couple the control and data plane entities. The Sensor Local Mobility Anchor's (SLMA) job is confined to maintaining Binding Cache management operations. The Dynamic Mobile Access Gateways (DMAG) are enriched by mobility anchoring functions with a unique set of global prefixes, maintain a Local Binding Cache (LBC) for the MNs attached to it to enable the sending and parsing of control messages to update the mobility sessions, act as a data plain router provided with links to the Internet, and offers no tunneling policy to forward packets to and from the Internet that do not imply paths traversing through SLMA. Secondly, it is to enhance fast handoff schemes based on the DSPMIPv6 architecture to reduce the handoff signaling cost and dropped packet size called Distributed Fast Proxy MIPv6 (DSPMIPv6). Thirdly, to develop a new Route Optimization (RO) scheme called Distributed Route Optimization (DRO), which provides fast recovery of the RO status after MN handoff using a low handoff signaling cost. The numerical and simulation results using the Omnet++ simulator, prove that the proposed DSPMIPv6 outperforms both PMIPv6 and SPMIPv6 in terms of the SLMA load by 54% and 56%, Signaling Cost by 28% and 25%, handoff latency by 69% and 61% and end-to-end delay by 45% and 65%. The simulation results prove that the proposed DFPMIPv6 scheme outperforms the PMIPv6, MFPMIPv6 and HFPMIPv6 in terms of handoff latency by 47 %, 56% and 52 % respectively, while guaranteeing a low dropped packet size by 79% compared with the basic PMIPv6. The use of DMAG has a good impact on the total performance. This is due to the provision of a buffer scheme close to the communicating DMAGs and reducing the handoff latency. Lastly the new DRO provides fast recovery of the RO status after MN handoff using a low handoff signaling cost. The simulation results prove that the proposed DRO scheme outperforms the previous work in terms of the wired link delay; the total cost was reduced by approximately 28% and 38% and total cost was reduced by 71% and 77% as compared with those of LIRO and ABRO, respectively.

CHAPTER 1

INTRODUCTION

1.1 Introduction

In recent years, the Internet of Things (IoT) is getting much attention by industry and academia due to its new trend of connecting different types of devices to the Internet without human intervention (Jamali et al., 2014, Sabella et al. 2016). Wireless Sensor Network (WSN) is considered as the core of IoT which uses sensing technologies for communication and nodes cooperate together to achieve their objectives. IoT will provide a wide range of smart applications and services like remote healthcare monitoring, intelligent transportation, smart environment, home automation, military and agriculture domains (Bojkovic et al., Jamali et al., 2014, 2013, Li et al., 2013, Zhou and Zhang, 2013,Yu et al., 2018).

WSNs are composed of tiny devices that are characterised by low cost, power, bandwidth, memory and processing. Information is sensed and collected from the environment and transmitted by WSN nodes hop by hop to the sink node through the network; the data are analysed in the sink node (Akyildiz et al., 2002).

The emergence of IoT and global computing has created the need to design protocols that can be used to connect WSN to the Internet. This development has the potential to change the mode of network operation. WSN applications have advanced because by using these protocols, can be connected with sensor nodes that have low capabilities. To turn IoT into reality, connecting WSN to the Internet for dissemination of sensed data is important because the Internet is the most widespread network

(Rodrigues and Neves, 2010). The interconnection of WSN and other Internet protocol (IP) networks, as well as the capitalization of existing Internet infrastructure and IP applications to sensor networks, can be facilitated by merging IP with WSN (Zinonos and Vassiliou, 2010, Chen et al., 2013). Moreover, mobility plays an essential role in the realisation of IoT through 'anytime' and 'anywhere' communication. However, mobility is not inherently supported by IP because the latter serves as a locator and identifier. As a locator, an IP address reaches a node through the use of a certain address; as an identifier, it is used by upper layers to identify the communication channel endpoint (Soto et al., 2010). Designing efficient mobility management is crucial because one of the crucial features of any wireless network is mobility. The aim of such protocols is to provide mobile users with the best service.

1.2 Research Background

In the new area of IoT research, mobility management protocols have become very important because in the current environment the static features of nodes have become obsolete. The aim of the mobility management protocols is to track and locate Mobile Nodes (MNs) efficiently to provide the user with full access to information irrespective of their locations. The separation of the IP address identifier role from the role of the locator in a manner, that the IP address cannot be changed whenever it is used as an identifier, but can be changed whenever the MN moves to a new network when used as locator is done by the mobility management protocols (Soto et al., 2010).

Standard bodies, such as the Internet Engineering Task Force (IETF), have presented various mobility management protocols. For instance, to address the global mobility of MNs, the IETF standardised the Mobile IPv6 (MIPv6) protocol (Johnson et al., 2004), which enables the continuity of a communication session for the host during movement. However, this protocol suffers critical performance in the areas of packet loss, signaling overhead, binding update and handoff latency (Kong et al., 2008). To enhance the performance of MIPv6, Hierarchical Mobile IPv6 (HMIPv6) and Fast Mobile IPv6 (FMIPv6) protocols were derived from MIPv6 by Soliman et al., (2005) and Koodli, (2005) respectively.

The MNs are involved in the mobility process of host-based mobility management protocols, which include MIPv6, FMIPv6 and HMIPv6. A significant degree of overhead is introduced by these protocols on the MNs, which are responsible for installing complex mobility protocols. Furthermore, in a situation where MN is unable to transmit the mobility-related signal, the functionality of mobility management protocols will be disabled (Zhang, 2008). Thus, IoT should have methods that can relieve MNs from being part of a mobility process, as well as reduce packet loss, handoff latency and a communication path (Bojkovic et al., 2013).

According to (Gundavelli et al., 2008), the IETF NEtwork-based Localized Mobility Management (NETLMM) working group gave a standard definition of Proxy Mobile IPv6 (PMIPv6) as a network-based mobility management protocol to find solutions to host-based protocol problems by moving the mobility functions from MNs to the elements of the network. Proxy Mobile IPv6 (PMIPv6) adds the Mobile Access Gateway (MAG) and the Local Mobility Anchor (LMA) as new entities.

Maintaining reachability to the MN address while it is moving in the local PMIPv6 domain is the most important function of the Local Mobility Anchor (LMA). The main function of the MAG is to detect the MN movements and activate the needed authentication signals with the Authentication, Authorisation and Accounting (AAA) server to register the MN with LMA. The MN's LMA address and network prefix and the allowed address configuration stage are required for the Mobile Access Gateway (MAG) to perform the registration process. The AAA server keeps all this information in a centralised or distributed manner (Korhonen and Muhanna, 2008).

The important characteristic of PMIPv6 is its network-based feature, in which the network identifies the node mobility and initiates the needed mobility signals to hinder the MN from participating in the handoff process. This characteristic enables the MNs, which only installed the conventional IP, to move freely among wireless networks without establishing complex mobility management protocols.

Considering both the network-based feature of PMIPv6 and the low capabilities of WSN, which makes the use of host-based mobility protocols like MIPv6 insufficient, researchers are motivated to use PMIPv6 for managing WSN mobility. For example, Sensor Proxy Mobile IPv6 (SPMIPv6) was proposed by Islam and Huh, (2011) as an adaptation of the PMIPv6 protocol. SPMIPv6 satisfies the needs of WSN as it reduces signaling cost, mobility cost and energy consumption. However, SPMIPv6 inherits most of the downsides of PMIPv6, such as the following: in PMIPv6, the LMA is involved in all registration and handoff operations, thereby increasing the handoff latency time. Moreover, PMIPv6 incurs a long data packet transmission time because all communication messages must pass through a Local Mobility Anchor (LMA) even though the communicating entities are located in the same network domain (Hwang et al., 2010a). In addition, this single central entity architecture leads to a single point of failure, and the system becomes vulnerable to the bottleneck problem. Moreover, an efficient buffering scheme during MN's handoff has not been considered; as a result, all packets that are sent during this handoff period are lost (Heijenk et al., 2008).

The Distributed Mobility Management (DMM) paradigm comprises a flatter system that moves the mobility functionalities close to the user and distributes the control and data planes at the edge of the access network (Chan et al. 2011). The major vision of the DMM framework is an all-IP infrastructure, where the flow of users' data is routed through the optimal path, multiple anchor points are exploited and IP services are posted closer to the users. Moreover, without the use of complicated dedicated support from MNs, this framework intends to support mobility across WSN (Zuniga et al. 2013). In addition, a mobile operator is given the flexibility to manage data traffic of users in accordance with an extended set of policies, such as whether IP flows should be anchored locally (for short-term sessions) or to a centralised node (for long-term sessions) as long as IP addresses are assigned wisely to the MNs in accordance with the available services (Cominardi et al. 2017). Two DMM approaches are available: the first one is Partially Distributed Mobility Management (P-DMM), which involves the distribution of data plane while the control plane remains central, and the second one is Fully Distributed Mobility Management (F-DMM), which involves the distribution of both the data and control planes. Lack of scalability, non-optimal routes and vulnerability of single point of failure and attack are some of the problems that come from the use of centralised mobility management (Lee et al. 2013) (Balfaqih et al. 2017) .

1.3 Problem Statement

On the basis of the discussions in the previous section, the summary of the limitations of PMIPv6 is given in the points below, as well as its extensions that present the problem statement of this study.

- In Sensor Proxy MIPv6 (SPMIPv6) protocol architecture is a centralized mobility management (CMM), The LMA control mobility and maintains a Binding Cache

Entry (BCE) for each MN to keep its binding information. Each MN is identified by its MN Identifier (MN- ID), Home of Address (HoA), and Care of Address (CoA). When the MN enters SPMIPv6 domain, all these information are added to the BCE by exchanging the proxy binding messages between LMA and MAG. In addition, involving LMA in data packets transmissions, cause the LMA to be extensively accessed to update the BCE as MNs keep moving and to forward the incoming packets which eventually leads to a bottleneck, a single point of failure, scalability problem, triangle routing, and tunneling overhead in LMA.

- The existing fast handoff schemes are not efficient because the majority of them were developed using principles of host mobility, which involve MNs in the mobility process. Therefore, a complex protocol stack is required to be installed by the MN, which is a contradiction of the principles of PMIPv6 for preventing the MN from participating in the mobility process. Furthermore, as a result of the participation of LMA in the handoff process, a long handoff signaling cost is incurred by the fast handoff schemes. This long handoff results in buffering overhead whereby incoming packets are buffered until the end of the handoff process because the completion of the handoff process cannot be forwarded. Moreover, fast handoff schemes may overload the network by multicasting the incoming packets to the old and new MAGs. The fast handoff schemes which are based on predicting the target MAG may fail due to the wrong prediction.

- The current route optimization schemes have either added extra signaling cost or they have not considered the case of recovering optimal route after MNs handoff. Furthermore, the majority of the proposed studies involve LMA in the handoff