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**Mobility Management and Packet Reordering
Processing in FiWi Networks**
基於光纖無線混合網的移動管理和包亂序
處理研究

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Abstract

Despite the good application prospect of hybrid Fiber-Wireless (FiWi) networks, there are still lots of design challenges to provide high quality communications (e.g., high bandwidth, low latency and seamless handover) for fixed/mobile users. Specifically, to improve the quality of communication for mobile users, it is a critical issue to achieve seamless handover which means no or negligible degradation in service quality during handover. To improve the quality of communication for fixed users, it is a challenging issue to increase the bandwidth since packet reordering may be generated by employing multi-path routing protocols.

In this dissertation, we will investigate mobility management and packet reordering issues to improve the quality of communication for both fixed and mobile users in FiWi networks. Specifically, we identify two problems as our research questions: 1) design of a novel handover framework to improve the handover performance and achieve seamless handover for mobile users, 2) design of packet reordering processing mechanisms to mitigate packet reordering and improve the TCP performance for fixed users.

For the first research question, we design a novel handover framework, an efficient mobility management protocol and a packet distribution algorithm to provide seamless handover for mobile users in FiWi networks. As a candidate wireless subnetwork of FiWi networks, Mobile WiMAX (MWiMAX) is a promising technology and also one of the key candidates for 4G cellular networks. In MWiMAX networks, a fundamental issue is seamless handover, which has been investigated extensively in the literature. However, there is a lack of comprehensive handover solutions that integrate the design

of MWiMAX network, backhaul technology, and Layer-3 (i.e., IP) mobility management. In this dissertation, we address this issue and propose a novel *handover framework* to improve the handover performance of MWiMAX networks. Specifically, our framework integrates a hybrid Passive Optical Network (PON) that enables efficient multicast, localized mobility management, and direct inter-base-station communication; the framework supports both hard handover and soft handover in MWiMAX; and the framework takes advantages of Mobile IP technologies and Media Independent Handover services of IEEE 802.21. Within the proposed framework, we develop an efficient *mobility management protocol (MIH-FHMIPv6)* for hard handover, and also design an efficient *packet distribution algorithm* for soft handover. Extensive performance analysis and numerical results show that (1) our mobility management protocol can significantly improve handover performance in terms of handover latency, signaling overhead, packet loss and packet reordering, and (2) the proposed packet distribution algorithm can effectively reduce the amount of packet duplication.

For the second research question, we design an efficient packet scheduling algorithm, a dynamic bandwidth allocation (DBA) scheme and an integrated flow assignment and resequencing approach to mitigate packet reordering for fixed users in FiWi networks. In a FiWi network, multi-path routing may be applied in the wireless sub-network to improve bandwidth. Due to different delays along multiple paths, packets may arrive at the destination out-of-order, which may cause TCP performance degradation. In this dissertation, we propose three mechanisms to improve in-order departure of packets from the OLT in a FiWi network and enhance the TCP performance. Firstly, we propose an effective *scheduling algorithm (SPCS)* at the OLT, which gives lower priorities to the packets which may potentially cause duplicate ACK (*dupack*) and reduce the congestion window size (*cwnd*). Secondly, we design a *DBA scheme (IPACT-MPR)* in the optical subnetwork (i.e., an EPON) which gives higher priorities to flows which may trigger TCP's fast retransmit and fast recovery algorithms in upstream bandwidth allocation. Finally, we propose an *integrated flow assignment and fast resequencing approach* which jointly determines the probability of sending pack-

ets along each path from the source and needs virtually zero resequencing delay at the OLT to reduce the out-of-order probability when packets are injected to the Internet from FiWi networks. Simulation results show that the proposed three mechanisms are effective in mitigating packet reordering and improving the TCP performance.

Keywords: Mobility Management, Seamless Handover, Packet Reordering, Multi-path Routing, PON, FiWi, Mobile WiMAX

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List of Acronyms

AR	Access Router
BS	Base Station
BU	Binding Update
CN	Correspondent Node
CoA	Care of Address
<i>cwnd</i>	congestion window size
<i>dupack</i>	duplicate ACK
DBA	dynamic bandwidth allocation
DRR	Deficit Round-Robin
EPON	Ethernet-PON
FBACK	Fast Binding ACK
FBSS	Fast Base Station Switching
FBU	Fast BU
F-HMIPv6	Fast Handover for Hierarchical MIPv6
FIFO	First-In-First-Out
FiWi	hybrid Fiber-Wireless
FMIPv6	Mobile IPv6 Fast Handovers

FSM	Finite State Machine
HA	Home Agent
HACK	Handover Acknowledge
HE	Handover Engine
HHO	hard handover
HI	Handover Initiate
HMIPv6	Hierarchical Mobile IPv6
HOL	head-of-line
IPACT	interleaved polling with adaptive cycle time
IS	information server
LBACK	Local Binding ACK
LBU	Local BU
LCoA	on-link CoA
LGID	Logical Group ID
LLID	Logical Link ID
MAP	Mobility Anchor Point
MDHO	Macro-Diversity Handover
MICS	MIH Command Service
MIES	MIH Event Service
MIH	Media Independent Handover
MIHF	MIH Function
MIIS	MIH Information Service

MIPv6	Mobile IPv6
MN	Mobile Node
MPCP	Multi-Point Control Protocol
MWiMAX	Mobile WiMAX
NLCoA	New LCoA
NONU	New ONU
OLT	Optical Line Terminal
ONU	Optical Network Unit
OOD	out-of-order
OWI	Optical Wireless Integration
PLCoA	Previous LCoA
PON	Passive Optical Network
PONU	Previous ONU
QoS	Quality of Service
RCoA	Regional CoA
RTO	retransmission timeout
SA	Simulated Annealing
SHO	soft handover
SPCS	Soft Precedence Constraint Scheduling
TDM	Time Division Multiplexing
UNA	Unsolicited Neighbor Advertisement
WDM	Wavelength Division Multiplexing