Media Independent Handover in Heterogeneous Networks

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Outline

• Scenario: Heterogeneous Networks
• Media Independent Handover (MIH)
  – IEEE 802.21 (Draft Standard)
  – MIH Services
    • Event
    • Command
    • Information
  – Modelling of the MIH Protocol
• Conclusion

IEEE = Institute of Electrical and Electronics Engineers
MIH = Media Independent Handover
Scenario: Heterogeneous Networks

LAN = Local Area Network
MAN = Metropolitan Area Network
WAN = Wide Area Network
Focus of IEEE 802.21

- Mobile terminals are surrounded by a multitude of
  - Devices
  - Networks
  - Different communication technologies
  - Business actors

- Problems to solve:
  - Handover between two link layer technologies has a break-before-make characteristic
  - IP connectivity may be lost completely => packet loss, high delays, and service disruption
  - Handover is not “seamless” for the application

“The standard specifies IEEE 802 media access-independent mechanisms that optimize handovers between heterogeneous IEEE 802 systems and between IEEE 802 systems and cellular systems.”

IEEE 802.21 has the goal to facilitate handovers and to maximize handover efficiency
Efficiency of Handovers

- **Control Plane**
  - Shorten/unify discovery, selection, and attachment phases
  - Support of make before break handovers
  - Minimize number of unnecessary handovers / handover signaling

- **User Plane**
  - Minimize impact of handovers on active services
  - MIH knows the following parameters
    - Packet Quality of Service (QoS) parameters
      - Minimum Packet Transfer Delay
      - Average Packet Transfer Delay
      - Maximum Packet Transfer Delay
      - Jitter
      - Packet Loss Rate
      - Packet Error Rate
    - Link QoS parameters
      - Link Throughput
      - Link Packet Error Rate
      - Supported Classes of Service
    - Class of Service (CoS) parameters
      - Class Minimum Packet Transfer Delay
      - Class Average Packet Transfer Delay
      - Class Maximum Packet Transfer Delay
      - Class Packet Delay Jitter
      - Class Packet Loss Rate
    - Mappings to technology specific parameters

\[
\begin{align*}
\text{Cos} & = \text{Class of Service} \\
\text{QoS} & = \text{Quality of Service}
\end{align*}
\]
MIH Function & Service Access Points

MIH User

MIH_SAP

MIH Function

MIH_NET_SAP

Transport Service Provider

Media-specific SAPs (802.3, 802.11, 802.16, 3GPP, 3GPP2, etc.)

MIH = Media Independent Handover
NET = Network
SAP = Service Access Point
MIH General Reference Model

MIH Function

MIH Event Service
MIH Command Service
MIH Information Service

MIH User
Layer 3 or higher
Mobility Management Protocol, eg.:
- Mobile IP for mobile node controlled mobility
- Proxy Mobile IP for network controlled mobility

Remote MIH Function
MIH_NET_SAP
L3
L2
MIH_NET_SAP
MIH_LINK_SAP
MIH_NET_SAP
LLC_SAP
Link Layer

L2 = Data Link Layer
L3 = Network Layer
LLC = Logical Link Control
SAP = Service Access Point
Event Service

- Link events are translated to media independent MIH events
- Subscription based
- Triggers may originate from local link events or in a remote system
- Several types of events
  - MAC and PHY state change events
  - Link parameter events
  - Predictive events
  - Link handover events
  - Link transmission events

MAC = Medium Access Control Sublayer
PHY = Physical Layer
• Translates MIH commands to link commands
• Commands are used for
  – Handover signaling and execution
  – Control of the behavior of a link
  – Configuration of event creation
  – Information retrieval
• Command may have its sink in a
  – Local node
  – Peer node
• Place of command execution may be within the peer’s
  – MIH user
  – MIH entity
  – Link layer
Information Service

- Data about neighboring networks in the geographical area of a mobile node
- Access network specific information
  - Operator
  - Roaming agreements
  - Costs
  - Security mechanisms
  - QoS
- Information for a dedicated point of access
  - Location
  - Data rate
  - Addressing
  - Type
  - Extensible with access network specific, service specific, or vendor specific information

QoS = Quality of Service
Point of Service, Point of Attachment

- Mobile node have always an MIHF entity
- Network nodes that implement the MIHF are either called
  - MIH PoS if they exchange MIH messages with a mobile node
  - MIH non-PoS if they exchange messages only with other MIH network nodes
- Network node with a layer 2 connection to the mobile node is called PoA
- PoA of the current link is called serving PoA
- In case of handover
  - Candidate PoA
  - Target PoA
- Node that does not offer layer 2 connections to mobile nodes is a non-PoA
Example of an MIH Network

PoA = Point of Attachment
PoS = Point of Service
RP = Reference Point

RP1/RP2/RP3

Serving PoA
Access Network a PoA
Core Network Operator 1 PoS
Visited Network
Home Subscriber Network
Core Network Operator 3 PoS
Internet
Information Database
Correspondent Node

Candidate/Target PoA
Access Network b PoA
Core Network Operator 2 PoS
RP1/RP3/ RP4/RP5
RP3/ RP4/ RP5
RP4/ RP5
RP4/

PoA = Point of Attachment
PoS = Point of Service
RP = Reference Point
• Service management allows
  – Capability discovery of an MIHF entity
  – Registration of MIH users at the MIHF
  – Subscription to MIH events
  – Setup the communication between MIHF entities

• Flow control
  – Limit rate of MIH messages
  – Rate-limiting of forwarded messages is out of scope
  – Token Bucket mechanism (RFC4443)

• MIH protocol acknowledgement service
  – Reliable data transport: message loss rate < 0.01
  – Acknowledged mode with retransmission timeout (RTO) calculation (RFC2988)

RFC = Request for Comments
RTO = Retransmission Timeout
Acknowledgement Service: Signal Flow Graph

Delay investigation with an ARQ Model of System a:

ARQ Model with 2 Retransmissions and handover from System a to System b:

A = Successful Transmission
ARQ = Automatic Repeat Request
B = Retransmission State
G(z) = Delay Generation Function
P = Channel Transition Matrix
R = Receive State
RTO = Retransmission Timeout
S = Send State
z = Delay Operator

Block Error Rate (BLER) of system $i$ given by $P_{1i}$.
Changing $P_{1i}$ if the BLER of the underlying channel increases.
=> The Hidden Markov Model (HMM) is exchanged.

Trigger Probability increases from retransmission to retransmission.
Network is a Time Varying System.
Acknowledgement Service: Analysis

pdf of System a (p=0.5)

pdf of System b (p=0.1)

pdf of the combined systems (2 retransmissions)

cdf for the three systems

cdf = Cumulative Distribution Function
pdf = Probability Density Function
Conclusion

• IEEE802.21 Overview
  – MIH Services
  – MIH Deployment

• Signal Flow Graph Model of MIH Protocol
  Acknowledgement Service
  – Allows calculation of an appropriate number of retransmissions
  – Allows to include MIH triggers
  – Allows investigation of sensitivity to triggers and Retransmission Timeout
  – Outlook: Include aspects of Time Varying Systems
Thank you for your attention!

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I haven't lost my mind -- it's backed up on tape ... somewhere.
Scenario: Heterogeneous Home Networks

- Multi-Mode Mobile Node 1
- Bridge
- Multi-Mode Mobile Node 2
- Access Point
- Home Network
- Gateway
- Internet
- Correspondent Node
- Home Subscriber Network
- Information Database
- Core Network Operator 1
- Node 3
- Node 4
- Nomadic Node 5

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The general model is specialized for the specific technologies IEEE 802.3, IEEE 802.11, IEEE 802.16, 3GPP, and 3GPP2.

MIHF offers three services:
- MIH Event Service
- MIH Command Service
- MIH Information Service

The MIH is implemented by a mobility management protocol, e.g.
- Mobile IP (RFC3775) for mobile node controlled mobility
- Proxy Mobile IP (PMIP) for network controlled mobility
- The MIH standard does not rely on a specific mobility management protocol

MIHF = Media Independent Handover Function
Example of IEEE802.21 in OMEGA

• Mobile Node 2 is a Mobile Node for Network 3 and a PoA for Mobile Node 1
• Direct communication between Mobile Node 1 and 2 is possible

PoA = Point of Attachment
PoS = Point of Service
MIH uses the four types of primitives: request, indication, response, and confirm.

Message exchange between the MIH function in the local and remote system via the MIH protocol.
MIH Protocol Frame & Header

MIH protocol frame

MIH protocol payload

MIH protocol header (8 octets)

Source MIHF identifier TLV

Destination MIHF identifier TLV

MIHF service specific TLVs

VER (4)

Ack Req (1)

Ack Res (1)

UIR (1)

M (1)

FN (7)

Rsvd1 (1)

MIH Message ID (16)

Rsvd2 (4)

Transaction ID (12)

Variable Payload Length (16)

Ack = Acknowledgement

AID = Action Identifier

FN = Fragment Number

MSB = Most Significant Bit

LSB = Least Significant Bit

M = More Fragment

Opcode = Operation Code

Req = Request

Res = Response

Rsvd = Reserved

SID = Service Identifier

UIR = Unauthenticated Information Request

VER = Version

M = More

F = Fragment

R = Request

S = Response

I = Information

U = Unauthenticated
**MIH Reference Points**

![Diagram of MIH Reference Points]

- **Candidate PoA**
- **MIH PoS**
- **MIH Non-PoS**
- **RP1**
- **RP2**
- **RP3**
- **RP4**
- **RP5**

**Legend:**
- **MN** = Mobile Node
- **PoA** = Point of Attachment
- **PoS** = Point of Service
- **RP** = Reference Point

**Network Entities:**
- **Non-PoS**
- **Serving PoA**
- **Non-PoA**

**Network Entity Connections:**
- MIH PoS to MIH Non-PoS via RP4
- Candidate PoA to MIH PoS via RP2
- MIH to MIH PoS via RP1
- MIH PoS to MIH Non-PoS via RP4
- MIH PoS to Non-PoA via RP3
- MIH Non-PoS to PoA via RP5
Flow Control (based on RFC 4443: ICMPv6)

- Limit rate of MIH messages
- Rate-limiting of forwarded messages is out of scope
- Token Bucket mechanism
  - Limiting the average rate of transmission to $N$, where $N$ can be either packets/second or a fraction of the attached bandwidth of a link
  - Allowing up to $B$ error messages to be transmitted in a burst, as long as the long-term average is not exceeded
  - The rate-limiting parameters should be configurable
  - In the case of a token-bucket implementation, the best defaults depend on where the implementation is expected to be deployed
Message Sequence Charts for Handover between WiMAX and two candidate WLAN access networks