Unified L2 Abstractions for L3-Driven Fast Handover
- Media Independent L2 Triggers from the Perspective of IP Layer -

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Outline

- L2 Abstractions for L3-driven Fast Handover
  - Goals of L3-driven fast handover
  - Architecture for control information exchange
  - L2 Primitives for L3-driven fast handover
- Details
  - Mapping of Primitives and Wireless LAN Parameters
- Evaluation
  - L3-Driven Fast Handover on FMIPv6
- Demonstration
  - L3-Driven Fast Handover on Predictive-LIN6
**Goal A: L3-Driven Fast Handover**

- **Current Sequence**
  - L3
  - L2
  - L3 Handover Preparation
  - Disruption
  - L3 Handover

- **L3-Driven Fast Handover**
  - L3
  - L2
  - L3 Handover Preparation
  - L2 Handover
  - L2-LinkStatus/PeerList
  - L2-PeerFound/Lost
  - L2-LinkToBeDown
  - L2-LinkConnect
  - L2-LinkUp
  - L3 Handover
  - Disruption
  - L3 Handover
Goal B: L3-Driven Vertical Handover

Continuous communication is difficult.

- L2-LinkStatus
- L2-LinkToBeDown
- L2-LinkConnect

Communication quality improves.

- L2-LinkConnect
- L2-LinkUp
**Request** is the acquisition request of the lower layer information or a registration of conditions for **Indication**.

In response, **Confirm** returns.

**Indication** is asynchronously delivered to an upper layer when an event which needs to be notified occurs.

In response, **Response** returns.
Usage Types of Primitives

Type 1. Provide L2 information to upper layers
- **request**: Acquisition request
- **confirm**: L2 information

Type 2. Notify upper layers of L2 events
- **request**: Registration for notification
- **confirm**: Valid or invalid
- **indication**: Asynchronous notification

Type 3. Control L2 actions from upper layers
- **request**: Control
- **confirm**: Ack or nack
L2 Primitives for L3-driven Fast Handover

- **L2-LinkStatus**
  - Acquisition request for the current link status.

- **L2-PeerList**
  - Acquisition request for the list of possible access points.

- **L2-PeerFound / L2-PeerLost**
  - Indication of discovery/missing of candidate access points.

- **L2-LinkUp / L2-LinkDown**
  - Notification that a new link is brought up / an existing link is brought down.

- **L2-LinkToBeDown**
  - Notification that the existing link is bringing down.

- **L2-LinkConnect / L2-LinkDisconnect**
  - Request for connection/disconnection of the specific link.

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**Link Quality Level**

- **VERY GOOD**: high quality
- **GOOD**: available (high watermark)
- **FAIR**: adequate quality
- **BAD**: low quality (low watermark)
- **VERY BAD**: unavailable
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L2 Primitives for Link Status

- **L2-LinkStatus**
  - Network Interface ID
  - Peer
    - MAC Address
  - Condition
    - Bandwidth
    - Link Quality Level

```
L2-LinkStatus
i/f id: ath0
peer {
  MACaddr: 01:23:45:67:89:ab
}
condition {
  bw: 2Mbps
  quality: GOOD
}
```

Link Quality Level
- VERY GOOD : high quality
- GOOD : available (high watermark)
- FAIR : adequate quality
- BAD : low quality (low watermark)
- VERY BAD : unavailable
L2 Primitives for AP Discovery

- **L2-PeerList**
  - Network Interface ID
  - Peer List
    - One or more [Peer*, Condition*] tuples

- **L2-PeerFound / L2-PeerLost**
  - Network Interface ID
  - Peer List
    - One or more [Peer*, Condition*] tuples

* Each **Peer** and **Condition** parameter consists of one or more sub-parameters, as described in the next slide.
L2 Primitives for L3 Handover

- **L2-LinkUp**
  - Network Interface ID
  - Peer
    - MAC Address

- **L2-LinkDown**
  - Network Interface ID
  - Peer
    - MAC Address
L2 Primitives for Preparing L3 Handover

- **L2-LinkToBeDown**
  - Network Interface ID
  - Peer
    - MAC Address
  - Condition
    - Bandwidth
    - Link Quality Level

![Link Quality Level]

**L2-LinkToBeDown**

i/f id: ath0
peer {
  MACaddr: 01:23:45:67:89:ab
} condition {
  bw: 2Mbps
  quality: BAD
}
L2 Primitives for L3-Driven Handover

- **L2-LinkConnect**
  - Network Interface ID
  - Peer
    - MAC Address

- **L2-LinkDisconnect**
  - Network Interface ID
  - Peer
    - MAC Address

```c
L2-LinkConnect
i/f id: ath0
peer {
  MACaddr: 01:23:45:67:89:ab
}

L2-LinkDisconnect
i/f id: ath0
peer {
  MACaddr: 01:23:45:67:89:ab
}
```
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What is FMIPv6?

- **L3 Fast Handover Protocol based on Mobile IPv6**
  - AR forwards data packets to the new location during L3 handover
L3-Driven Fast Handover on FMIPv6

- L3-Driven + FMIPv6 Predictive Mode
L3-Driven Fast Handover on FMIPv6

- FMIPv6 Reactive mode
  - The case that handover prediction failed.
FMIPv6 Implementation for BSD: TARZAN

- By Nautilus6 Project
  - http://www.nautilus6.org/
- Based on SHISA
  - Mobile IPv6 and NEMO implementation for KAME (*BSD)
    - http://www.kame.net/
- Support both MN and AR
- L2 trigger by LIES
  - Inter-Layer Control Information Exchange Architecture
  - L2 Abstraction:
- Manual CAR (Candidate Access Router) installation
  - car_info.conf
- Buffering is not supported yet.
Evaluation of L3-Driven Predictive FMIPv6
(without Buffering)

Total Disruption Time: 60ms(L2) + 50ms(L3) = **110ms** / **L2**: Wireless Environment Emulator
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L3-Driven Fast Handover on Predictive-LIN6

- **Current Sequence**

  - L3
  - L2

  L3 Handover Preparation
  Delay

  L3 Handover

  More than 1 sec
  More than 1.5 sec

  Disruption

- **L3-Driven Fast Handover**

  - L3
  - L2

  L3 Handover Preparation
  L2-LinkToBeDown
  L2-LinkConnect
  L2-LinkUp

  L2 Handover

  Disruption
Demonstration of L3-Driven Fast Handover on Predictive-LIN6

- Application: DVTS (15Mbps)
  - Digital Video Stream on IEEE1394 Encapsulated into IP
  - Sender: MN in a car
- L3 Mobility Protocol: Predictive-LIN6 (No Forwarding, No Buffering)
  - Prediction of LinkDown and Candidate AP/AR by L2 Triggers
  - DAD is performed before L2 handover
- L2: IEEE802.11a (5GHz, 54Mbps)
  - All APs are same channel
  - All APs have different SSID
- Project: SIMPLE
  - Smart Internet Mobile Project with Layered Effects

Handover: L2 (1-2ms) + L3 (RTT 1-2ms)
LinkToBeDown (Prepare L3 Handover)
→ LinkConnect (L2 switch to a specified AP)
→ LinkUp (Finish L3 Handover)
Sequence of L3-Driven Fast Handover on Predictive-LIN6

Sequence of L2 and L3 Handover: 3-4ms (L3 Disruption Time)

Sequence of L2 Trigger: 40us

- **L3**
  - Link Connect
  - LinkDown

- **L2**
  - LinkUp
  - 0.8 ms

- **Wireless Device**
  - L2 Event

- **Kernel**
  - 2.6 us

- **Userland Daemon**
  - 13.1 us

- **Indication**
  - 19.8 us

- **Address Configuration**
  - Location Registration

- **RTT: 1-2 ms**

- **Time**
Summary

- Designed L2 abstractions as primitives.
  - L2-PeerList / L2-PeerFound / L2-PeerLost
  - L2-LinkStatus / L2-LinkUp / L2-LinkDown / L2-LinkToBeDown
  - L2-LinkConnect / L2-LinkDisconnect
- L3-driven fast handover on FMIPv6 was evaluated.
- L3-driven fast handover on Predictive-LIN6 demonstration.

IETF Document:

Nautilus6 Project  http://www.nautilus6.org/
SIMPLE Project