Inter-technology handoff in Next Generation Mobile Networks (NGMN)

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Outline

- Wireless technologies
- Handoff problem
- soft handoff approach
- Conservative soft handoff
- Some results, some analysis
- conclusion
Technologies

- 5.4 billion mobile users, 7.6 billion in 2015
- 3.6 exabytes per month mobile data in 2014

For more details, see Appendix B Forecast and Methodology.
Source: Cisco Visual Networking Index, 2010-2014

3GPP technologies
- GPRS, EDGE (2.5G, 2.75G)
- UMTS, HSPA, HSPA+ (3G, 3.5G)
- Long Term Evolution (LTE), LTE-Advanced

IEEE technologies
- WiMAX (mobile WiMAX, 802.16e)
- WiMAX 2 (802.16m, to be released)
- WiFi
- LTE-Advanced and WiMAX 2 submitted to ITU for IMT-Advanced
LTE: Introduction

- Released in Dec. 2008 by 3GPP.
- Currently 6 networks in service, 160 commitments

5 msec

LTE: Field trial

- Ralf Irmer et al. describe two field trial in Dresden and Berlin, Germany [1]
- Dresden downtown trial focuses on PHY layer.
- Berlin trial is for evaluating applications
LTE: Field trial

Figure 1. Field test area in Dresden.[1]

Figure 2. Test base station with antennas and microwave link at central site.[1]
LTE: Field trial

Figure 3. Signal coverage of the trial area based on drive tests. [1]

LTE: Field trial – Border throughput

Figure 5. Cell border throughput vs. system spectral efficiency for LTE DL with different antenna systems and precoding matrices.
LTE: improvement techniques

- Heterogeneous networks [2]

- Multiuser diversity [3]
LTE: improvement techniques

- Multiuser diversity [3]
  - For $K$ users the capacity gain is $O(\log (\log (K)))$
- If shadow fading is also considered the gain is $O(\sqrt{\log(k)})$ [4]
Mobility and Seamless Handoff

- Handoff process:
  - Scanning
  - Network selection
  - Authentication and Authorization
  - IP address configuration
  - Routing information update

- Handoff can be too time consuming
- Soft handoff (SHO) can be used
Mobility and Seamless Handoff

- Soft Handoff (SHO) approach
  - Two active interfaces
  - Duplicated data packets are received

![Diagram of MS movement from RAN1 to RAN2]

Figure 1. MS movement from RAN1 to RAN2

Soft handoff methods

- Soft handoff in the application layer: mSIP [5]
- Transport layer: MMSP [6]
  - Adds FEC to packets
Soft handoff methods

Figure from [6]

Soft handoff methods

SNR for MPEG4 video

Figure from [6]
Soft handoff methods

- IP layer SHO: look at [7] for an example

![IP layer SHO](image)

Soft handoff drawbacks

- The mobile station (MS) should have multiple radio interface
- Excessive power usage
- Consumption of radio resource usage
- Cell-edge capacity problem.
  - Handoff usually happens in cells edge
- In some cases soft handoff is used only for signaling

![Soft handoff drawbacks](image)
Our Conservative SHO (cSHO)

- Only one active interface at a time
- The radio interface with lowest PER is active
Our Conservative SHO (cSHO)

- Only one active connection → Less resource consumption
- We can use shadow fading to improve capacity
- There is a signaling cost for feedback
  - We use IEEE802.21 → Large packets
- More complexity due to buffering and forwarding
  - Much less than Cooperative Multipoint Transmission (CoMP)
- Some battery consumption for running the algorithm and monitoring interfaces

Our Conservative SHO (cSHO)

- More packet loss compare to SHO
  - We need to evaluate the performance of cSHO and SHO
Simulation Results

- Received VoIP packets per second

![Graph showing received VoIP packets per second over time. The graph compares two lines: HHO and SHO, with Time (sec) on the x-axis and Received VoIP packets (packet/second) on the y-axis. The graph highlights the performance of both HHO and SHO over a period of 45 seconds.]
Simulation Results

- Received VoIP packets per second

Performance evaluation

- Performance criteria:
  - Packet Error Rate (PER)
  - Probability of outage
  - Handoff accuracy; Matching Rate
  - Handoff delay; signaling delay

- Cost analysis:
  - Signaling cost
  - Complexity: network modifications, protocol stack modifications
Performance evaluation

- Cost analysis (cont.)
  - Radio resource consumption & battery consumption
  - Backhaul link capacity usage

Performance evaluation: Packet loss

- PER1 and PER2: packet error rate of interface 1 and 2.
- SHO PER = PER1 * PER2
- HHO PER = PER1 or PER2
- cSHO PER = min{PER1, PER2}
- cSHO Gain: \[ G_{cSHO} = \frac{PER_{HHO}}{PER_{cSHO}} \]
- SHO Gain [7]
Performance evaluation: Packet loss

- Radio channel with shadow fading:

```
\begin{tikzpicture}
  \draw[->] (0,0) -- (0,5) node[above,black] {Received Signal Strength (RSS)};
  \draw (0,0) -- (3,0) node[below,black] {Good};
  \draw (0,0) -- (3,2) node[below,black] {Average};
  \draw (0,0) -- (3,4) node[below,black] {Bad};
  \draw (0,0) -- (3,5) node[below,black] {Outage};
\end{tikzpicture}
```

- HHO with hysteresis: do handoff if current RSS is less than average and target RSS is above average
- SHO and cSHO don’t need hysteresis
- We need to use Markov State Model for the radio channel:
  - Find the probability of being in each state
  - Find the probability of using each interface in each state
  - Find the gain in each state assuming using each interface
  - Find the average gain
Some ideas

- cSHO with multi-interfaces, multi base stations
  - All base stations have packet datas
  - BS with the best conditions sends the packet
- Dynamic Auction in packet forwarding
  - The cheapest BS sends the data

Conclusion

- With HHO it is hard to achieve seamless handoff
- SHO provides seamless handoff with the best packet delivery performance
- SHO causes capacity problems
- cSHO provides good packet delivery ratio while saving some resources
- cSHO adds more complexity to networks.
References


[7] Jianwen Huang; Ruijun Feng; Yana Bi; Wu, J.; Mei Song; “A IP Layer Soft-handover Approach for All-IP Wireless Networks”, 2005