End-to-end IP Service Quality and Mobility

- Lecture #4 -

Special Course in Networking Technology

S-38.215

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Planned contents & draft schedule

1.	Introduction	Jan 13th
2.	Characteristics of mobile applications	Jan 20th
3.	Service quality requirement characterizations	Jan 27th
4.	**Challenges of mobile environment**	Feb 3rd
5.	Mobility and QoS in GPRS	Feb 10th
6.	Mobility and QoS in 3GPP systems	(Feb 17th)
7.	Mobility and QoS with Mobile IP	(Feb 24th)
8.	Mobile IP QoS enhancements	(Mar 3rd)
9.	Edge mobility	(Mar 10th)
10.	Inter-system mobility	(Mar 17th)
11.	End-to-end QoS management	(Mar 31st)
12.	Summary	(Apr 7th)

Dates in parentheses to be confirmed

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Agenda

- Goal of the lecture
- Definition of mobility-related concepts
- Scenarios for mobility
- Service quality challenges in IP mobility systems
- Mobility modelling
- Conclusions for service quality support

Goals of the lecture

- Define generic mobility-related concepts that can be used for cellular & IP-based mobility systems.
- Study mobility related issues using example scenarios.
- List challenges for service quality in mobile environment, and common techniques for addressing them.
- Basic understanding of mobility modelling.

Mobility-related concepts

- **Nomadicity** = ability to connect to network in different locations.
  - Also known as portability.
- **Mobility** = ability to maintain sessions
  - While moving physically.
  - While switching between access technologies.
- An **IP address** has two rôles for an endpoint:
  - Identification of an endpoint for socket connection.
  - Identification for a route to the endpoint
- When the endpoint supports mobility, separate addresses may be needed for these purposes.

[C. Perkins, *Mobile IP – Design Principles and Practices***]**

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Mobility-related concepts, cont'd

- **Reachability address**
  - Address via which the endpoint can be reached.
- **Point of Attachment** (PoA):
  - Routing address for the endpoint.
- **Examples**:
  - GPRS/3G:
    - Endpoint receives its IP address from gateway.
    - IP reachability address = IP-level PoA.
      - GPRS-level PoA invisible to end application.
  - Mobile IP:
    - Endpoint receives its IP address from access router.
    - Reachability address != PoA if away from home link.

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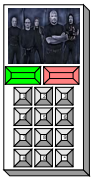
Scenarios

- Assumption: service instance can be maintained during mobility.
- Scenario #1: Britney is walking downtown Helsinki and using WAP with her GPRS terminal to access the home page of her favourite rock group.
  - End user service quality level is negotiated between the terminal and the GPRS network.
  - Mobility management is handled beneath the end user IP layer.
  - IP address stays the same.
  - QoS control on GPRS layer.



Scenarios, cont'd

- Scenario #2: Britney is walking about Helsinki with a laptop equipped with a 802.11 PCMCIA card, every now and then stopping in a café and browsing the Internet.
  - End user service quality provisioned by the operator.
  - Service quality more directly coupled to user IP layer.
  - If session needs not be maintained between browsing sessions, may be implemented within the category of nomadicity.
    - Operator needs to take into account service quality consistency.
  - If session continuity needed, MIPv4 or MIPv6 can be used.
    - Handover performance needs to be considered.

Scenarios, cont'd

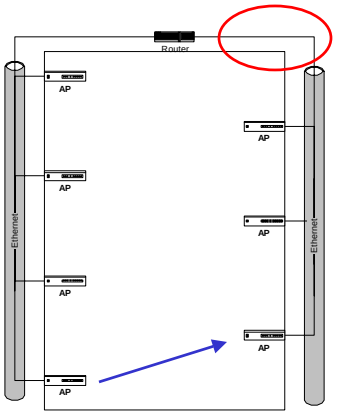
- Scenario #3: Britney is sitting in a car downtown Helsinki with a laptop sporting WCDMA/802.11 PCMCIA card, watching streamed video.
  - WLAN used in hotspots, WCDMA outside them.
  - End user service quality provisioned by the operators.
  - Available bandwidth can be larger in WLAN hotspots (up to 11 Mbit/s).
  - Service quality needs to be consistent between access technologies.
  - Handover between access technologies should be as seamless as possible.
    - Authentication.

Service quality challenges

- Reachability challenge: how to locate an endpoint?
  - L1 answer: 21000 km long RJ45 cable ☺.
  - L2 answer: GPRS / 3G + roaming agreements.
  - L3 answer: MIPv4 / MIPv6.
  - L4 answer: SIP.
- Mobility between PoAs (L2 or L3).
  - Continuity, service instantiation time, service event level performance.
- Mobility between access technologies.
  - Continuity, service instantiation time, service event level performance, reachability.

Challenges: inter-PoA mobility

- Variable loading.
  - Number of users behind the L2/L3 PoA may vary.
  - Distribution of service event types under the PoA may vary.
- Handover performance.
  - Connection rerouting.
  - Possible inter-PoA state transfer.
- Topological challenges.
  - PoAs physically close to each other may be logically distant from each other.



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Challenges: inter-technology mobility

- Varying service quality support capabilities.
  - One technology may have more advanced service quality support capabilities than other(s).
  - QoS model may be different.
  - Example: WCDMA -> 802.11 with BE transport.
- Control layer support for inter-technology mobility.
  - Scalability and performance of AAA.
  - Interworking between access technologies: SLAs.
- Inter-technology switchover performance.
  - Re-routing of flows.
  - Possible establishment of state.

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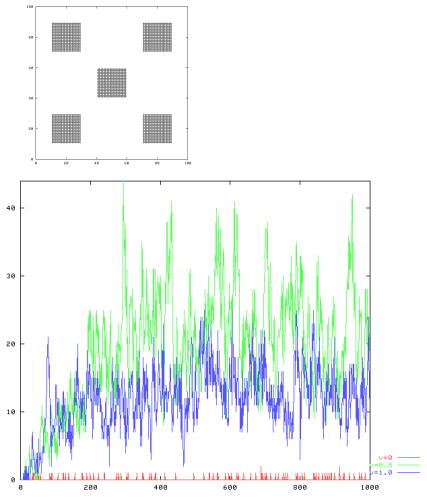
Ad hoc networks

- Ad hoc networks do not have predefined infrastructure.
  - Mobile nodes fixed but topology not constrained.
    - E.g., “wireless routers” on 2.4GHz band.
  - Network nodes may be moving.
    - E.g., 802.11 clients in infrastructure-less mode.
- Challenges:
  - Topology variable.
    - Large share of overall traffic may need to be routed over small number of nodes.
    - Routing updates.
  - Service quality support mechanisms need to be adaptive.
  - QoS model.

Ad hoc networks – simple example

- Topology:
  - Square “world”
  - Square obstructions embedded.
- Per-node mobility modelled.
- Each node runs DV routing algorithm.
- Each endpoint chooses other end randomly.
- #(Xmit attempt) vs. time for different velocities.

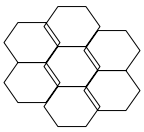


Service quality control for mobility

- Topological diversity.
  - Use multiple PoAs simultaneously.
  - "Make before break".
- End-to-end service quality downgrading / renegotiation.
  - Guaranteed performance vs. shared capacity.
  - Can also be implicit – different kinds of end user SLAs for different technologies.
- Interrupted communication.
  - Shift service instance / event in time.
- Connection blocking/dropping.
  - Continuity/availability may be standardized or defined in end user SLAs.

Mobility modelling

- Example: wireless access.
- Each wireless access point has N users $\{u_i\}$ using it as (one) PoA.
  - Coverage area defines a cell.
- Coverage areas of access points may overlap.
- Macromobility related to users switching from one cell to another one.
  - With topological diversity, users may still stay connected to the previous PoA.
- Modelling options:
  - Aggregate level modelling.
  - Endpoint level modelling.



Aggregate modelling for mobility

- Types:
  - **Fluid models**: asymptotic approximation for average mobility rates.
  - **Markovian models**: mobility modelled by transition probabilities.
  - **Gravity models**: mobility dependent on density of nodes in each cell.
  - **Hierarchical mobility**: modelling uses multiple levels of cells: pico/micro/macrocells.
- To note:
  - Are variations in mobility rates accounted for.
  - Rate uniformity (preferred routes).

$$r = \frac{\rho V L}{\pi}$$

[S. Grech,*Optimizing mobility management in future IPv6 mobile networks***, HUT, 2001]**

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Endpoint level modelling of mobility

- Endpoint mobility needs to be modelled.
  - Random walk.
  - Gravity model.
  - Effect of simulation area edge: periodic / rigid / …
- Communication pattern needs to be modelled.
  - Model for service instantiation: Poisson/…
  - Model for service instance duration: exponential/…
  - Accuracy of service instance modelling: pkt level / aggregated.
- Routing & connectivity needs to be simulated.
  - Event simulators: ns2, GloMoSim.

[C. Perkins (ed.),*Ad Hoc Networking***, Addison-Wesley, 2001]**

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System-level modelling for service quality

- Methodology depends on the goal of modelling:
  - Given anticipated traffic volumes, decide the best possible network topology and element capacity.
  - Given the network topology and element capacities, find out how much traffic one can accommodate into the network.
  - Given the network topology and anticipated traffic volumes, find out optimal element capacities.
- Appropriate level of detail:
  - Average modelling applies better higher up in the topology (CLT).
  - Statistics of variations more important in first access links.
- Edge treatment.

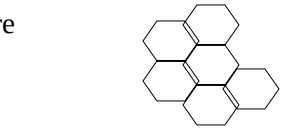
System-level modelling, cont'd

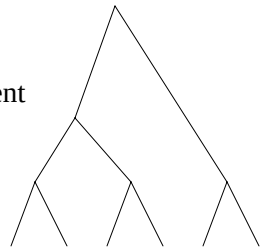
- Advanced mobility modelling
  - Preferred routes for given endpoints.
  - Movement attraction points.
  - Speed distributions: vehicles, pedestrians.
- Advanced temporal modelling for large-area simulations.
  - Rush hours: people get to work.
  - Evening: shopping peak.
  - Affects mobility model, too.
- Advanced endpoint modelling.
  - Different user segments in different locations.

[J.G. Markoulidakis et al., *Mobility modelling in 3rd generation…*, **IEEE personal comm., Aug'97]**

Example

- Find out how much traffic can be accommodated into the network when topology & capacities are given.
- Need to know:
  - Service usage pattern in an endpoint.
  - Service instance composition.
  - Service performance targets per service event type.
  - Edge treatment capabilities.
  - Service quality support capabilities.
  - Which PoAs are physically adjacent.
  - Mobility model for endpoints.





Example, cont'd

- Endpoint level modelling, packet event simulator assumed.
- Let's make it as simple as possible.
  - AP link layer capacities = $\{o_i\}$, i = 1..6.
  - Network link capacities = $\{l_i\}$, i = 1..10.
  - Single service, single event / service instance.
  - Inter- service instance separation: $P(s) \sim exp(-\alpha t)$.
  - 95% percentile for end-to-end delay: D.
  - Edge treatment: dropping => token bucket parameters.
  - Adjacency: given.
  - Velocity distribution spatially uniform, single velocity v for all nodes.

Example 2

- Endpoint level modelling w/packet simulator.
- DiffServ transport network.
- As before, but with N service types.
  - Each service instance types consist of M_i service events with inter-event temporal separations $P(s) \sim exp(-\beta_i t)$, $i=1,N$.
  - Inter- service instance separations: $P(s) \sim exp(-\alpha_i t)$, $i=1,N$.
  - 95% percentile for end-to-end delay: D_i, $i=1,2$.
  - Edge treatment: dropping => N x token bucket parameters.
  - DiffServ parameters (WRED not assumed):
    - Rate limiter setting for EF.
    - Scheduling weight for AF.

Conclusions

- Service quality support capabilities vary in mobile systems:
  - GPRS/3G networks: service quality managed on link layer.
  - Mobile IP networks: systems for handling service quality support need to be built into control layer.
  - Ad hoc networks with variable topology: challenging.
- Service quality model should reflect mobility support capabilities of the access technology.
  - Supporting of rigid service quality guarantees can be costly in terms of network capacity.
- Modelling.
  - Sensitivity analysis.
- Inter-technology handovers.