

Pervasive Networks and Ambient Intelligence Applications: Local Solutions to Improve Communication Performance in Mobile Scenarios

Olivier Mehani <olivier.mehani@mines-paristech.fr>
Supervisors: Roksana Boreli (Nicta), Thierry Ernst (Inria)

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Discussion

Use-case Scenarios

Multiple, Dynamic, Contexts

Intelligent Transportation Systems

- ▶ move at tens of kph along roads
→ **short connection times** with elements of the infrastructure;
- ▶ quickly passing in the vicinity of one another (opposite direction, crossroads)
→ **short (direct) connection times** to peers;
- ▶ going in the same direction (same road)
→ **slowly evolving topology** with longer connection times.

“Pocket Mobility”

Walking unstructured moves at a couple of kph
→ **temporary connections** to the infrastructure;

On-board same conditions as ITS;

Static (or in a equipped vehicle)
→ using **locally static networks**.

Use-case Scenarios

Multiple Technologies

Possibly **simultaneous** use of

- ▶ Physical technologies:
802.11a/b/g/p (managed or ad-hoc), GSM (GPRS/UMTS), 802.16e;
- ▶ Mobility management at the routing layer: AODV/OLSR, MIP/(MA)NEMO, Geographical routing.

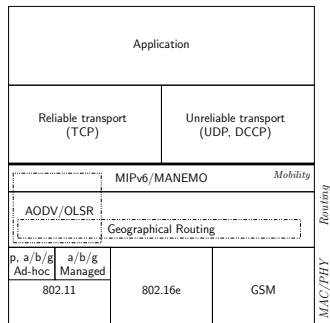
Example multihomed node:

Wi-Fi ad-hoc local neighbors, mesh routing algorithm;

Wi-Fi managed internet access via local infrastructure;

WiMAX internet access, slower but more widely available;

MANEMO mobility support.



Use-case Scenarios

Requirements

Frequent changes in the network topology create **short-lived network paths**.

⇒ Use resources **as much and as soon as possible**:

- ▶ network path **capacity detection** (*i.e.* maintain valid estimations of the available bandwidth);
- ▶ **connectivity information** (*e.g.* to send binding updates, discover new neighbors or resume previous data traffic);
- ▶ use of the **shortest path available** (*cf.* Manabu's work on route optimization).

Primary focus on **infotainment** (*e.g.* content access or streaming) and **non safety-oriented** (*e.g.* road traffic or environment information) applications in mind.

Use-case Scenarios

Open Issues

Adaptation of higher layers (transport, application) to support changes or disappearance of connectivity

Objective: adaptive update of layers parameters,

Metrics: amount of unused but needed resources ;

Transmission of relevant information between layers to optimize the overall behavior

Objective: detect changes and adapt parameters

Metrics: delay before full adaptation,;

Trust assessment mechanism before establishing new routes

Objective: prevent address spoofing,

Metrics: spoof success rate, overhead, delays.

Use-case Scenarios

Open Issues

Adaptation of higher layers (transport, application) to support changes or disappearance of connectivity

Contribution: transport protocol able to suspend transmission and re-evaluate the network capacity ;

Transmission of relevant information between layers to optimize the overall behavior

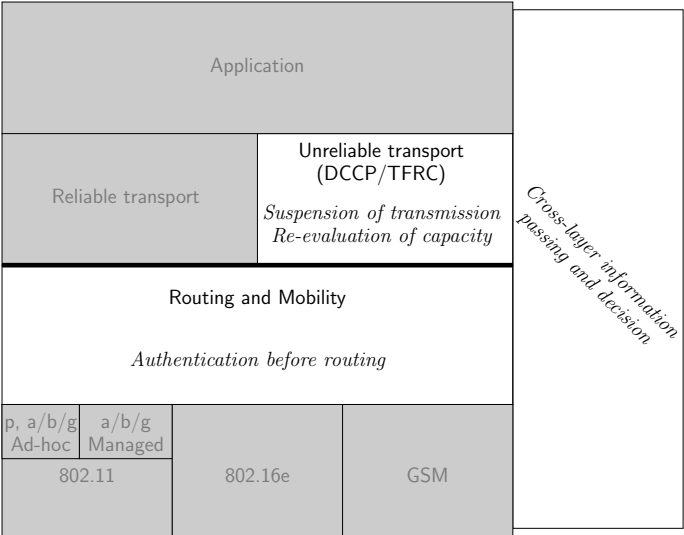
Work in progress: external control system making decision based on abstracted layer information;

Trust assessment mechanism before establishing new routes

Idea: certificate-based authentication of addresses and prefixes owners.

Use-case Scenarios

Open Issues



Transport Layer Disconnection Mitigation Techniques

Quick outline

Contributions:

- ▶ Evaluation of the [effect of network path disruption](#) on congestion control mechanisms (June 2008);
- ▶ [Model of the TCP-Friendly Rate Control behavior](#) when disconnections occur;
- ▶ [Disconnection- and network capacity changes-aware adaptation of TFRC](#) and implementation into the Datagram Congestion Control Protocol.

Transport Layer Disconnection Mitigation Techniques

DCCP/TFRC for Real-time Traffic

Not all traffic requires end-to-end reliability → trade-off with timeliness of data.

- ▶ The **Datagram Congestion Control Protocol** is an interesting replacement to non-congestion aware UDP to **carry real-time traffic over shared networks**.
- ▶ DCCP can use the TCP-Friendly Rate Control for congestion control.
- ▶ TCP-Friendly Rate Control Protocol:
 - ▶ rate-based congestion control mechanism
 - ▶
$$X_{\text{Bps}}(p, R) = \frac{s}{R\sqrt{\frac{4p}{3}} + t_{\text{RTO}}\sqrt{\frac{27p}{8}}p(1+32p^2)}$$
 - ▶ mimicks TCP's behavior;
 - ▶ provides TCP-fair congestion control to other transports.

Transport Layer Disconnection Mitigation Techniques

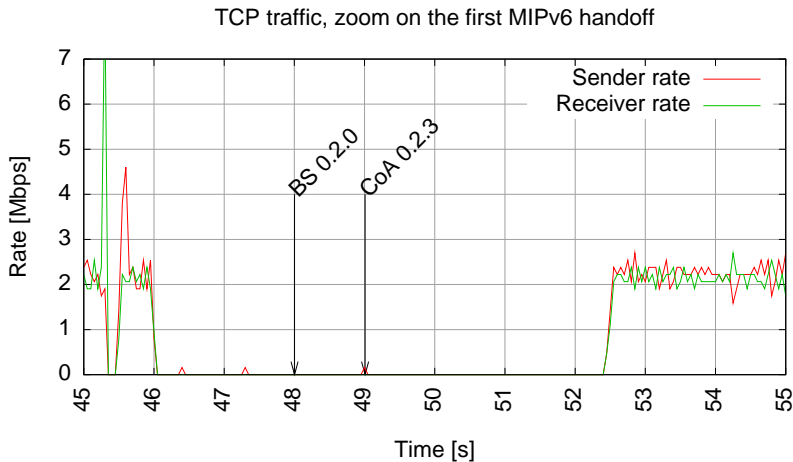
June 2008 Summary: Bad Interactions of Mobility and Transports

Preliminary study: impact of loss of connectivity on transport protocols.

- ▶ Two types of handoffs
 - horizontal** from one network to the other,
 - vertical** from one physical technology to the other.
- ▶ Both create **temporary disconnections** which cause **packets to be lost**.
- ▶ Congestion control algorithms **wrongly interpret** these losses as a congestion, and consequently reacts by **reducing the sending rate**.

Transport Layer Disconnection Mitigation Techniques

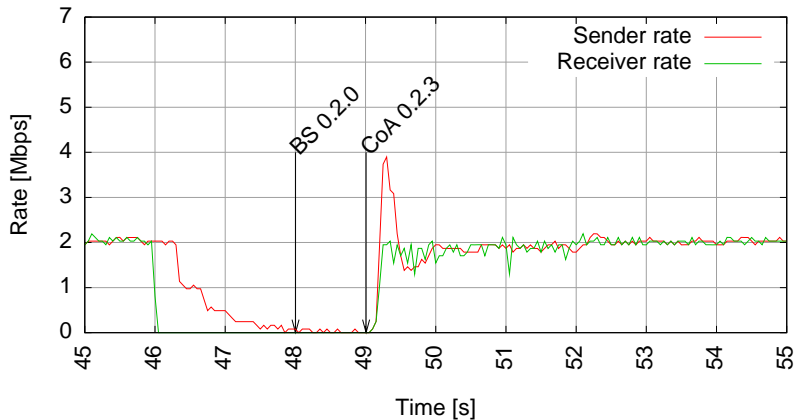
June 2008 Summary: Bad Interactions of Mobility and Transports



Transport Layer Disconnection Mitigation Techniques

June 2008 Summary: Bad Interactions of Mobility and Transports

DCCP CCID 3 traffic, zoom on the first MIPv6 handoff

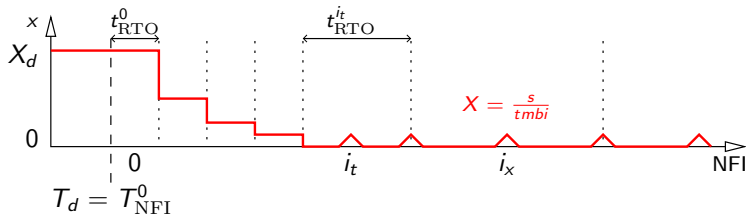


Transport Layer Disconnection Mitigation Techniques

Disconnected TFRC Model

When a disconnection occurs and until the node is fully reconnected

- ▶ feedback messages from the receiver can no longer be received;
- ▶ the sender gradually reduces its sending rate then,
- ▶ it increases its retransmission timeout.



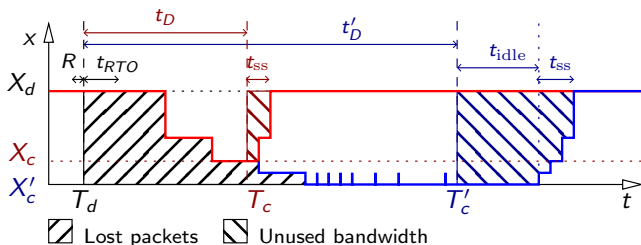
Transport Layer Disconnection Mitigation Techniques

Disconnected TFRC Model

During the disconnected period, all packets sent are lost.

Upon reconnection

- ▶ the sender doesn't restart sending until its retransmit timer has expired;
- ▶ the rate is increased through a slow-start phase.



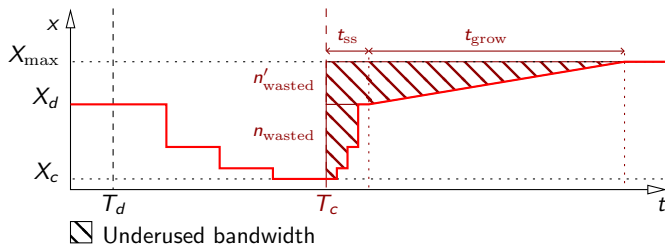
⇒ Lower computed sending rate due to losses and sub-optimal use of the available bandwidth (both in time and volume).

Transport Layer Disconnection Mitigation Techniques

Disconnected TFRC Model

If the new network path offers a larger capacity than before

- ▶ **slow-start** to the computed sending rate then,
- ▶ **even slower increase** as the loss-event rate reduces.



⇒ **Better network path capacity wasted** during a very long period.

Transport Layer Disconnection Mitigation Techniques

Disconnected TFRC Model

Losses and “wasted” bandwidth during and after a disconnection

$$n_{\text{lost}} = \begin{cases} \left\lfloor \frac{7}{8} \frac{t_D X^0}{s} \right\rfloor & (t_D \leq t_{\text{RTO}}^0) \\ \left\lfloor \frac{7}{8} \frac{t_{\text{RTO}}^0 X^0}{s} + \sum_{i=1}^{i_D-1} \frac{t_{\text{RTO}}^i X^i}{s} + \frac{t_{\text{RTO}}^{i_D} X^{i_D}}{2s} \right\rfloor & (\text{otherwise}) \end{cases} \quad (1)$$

$$n_{\text{wasted}} = \frac{1}{s} \left(t_{\text{idle}} \cdot X_d + \sum_{i=0}^{n_{\text{ss}}} R_{\text{new}} (X_d - 2^i X_c) \right) \quad (2)$$

$$n'_{\text{wasted}} = \frac{1}{s} (X_{\text{max}} - X_d) (t_{\text{idle}} + t_{\text{ss}}) + \frac{R_{\text{new}}}{s} \sum_{i=0}^{n_{\text{grow}}} (X_{\text{max}} - X^i) \quad (3)$$

Transport Layer Disconnection Mitigation Techniques

Disconnected TFRC Model

| Possible performance improvement | | | | |
|---|------|--------|---------|---------|
| from \ to | UMTS | 802.16 | 802.11b | 802.11g |
| Packet losses (1) | | | | |
| UMTS | 306 | 236 | 226 | 224 |
| 802.16 | 2760 | 2614 | 2614 | 2614 |
| 802.11b | 1080 | 1078 | 1078 | 1078 |
| 802.11g | 2909 | 2907 | 2907 | 2907 |
| Unused bandwidth (2) & (3) [500 B packets] | | | | |
| UMTS | 0 | 82938 | 263 | 109541 |
| 802.16 | 0 | 471 | 155 | 1029 |
| 802.11b | 0 | 0 | 1085 | 54674 |
| 802.11g | 0 | 0 | 0 | 4699 |

▶ Compare to simulation results

Transport Layer Disconnection Mitigation Techniques

Temporarily “Freezing” the Transport to Avoid Losses

Related work: Freeze-TCP can temporarily suspend a TCP connection

- ▶ in case of **predictable disconnections** on the receiving end;
- ▶ **rate restored to previous value** when connectivity is back;
- ▶ **performance improvement in mobility situations** (e.g. on-board vehicle computer).

⇒ Design the same functionalities for TFRC into DCCP [1, 2].

Additional features:

sender-based freezing to account for mobile senders;

slow-start-like probing for better capacity along the new path.

Transport Layer Disconnection Mitigation Techniques

Additional states and options needed to support freezing

Freeze-DCCP/TFRC mechanism:

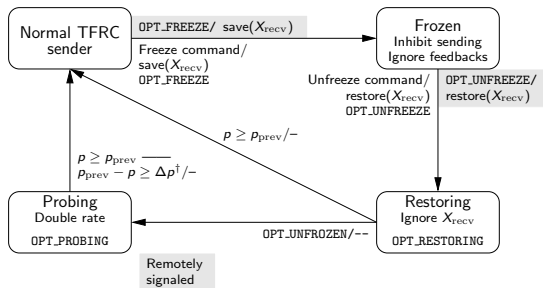
tight cooperation between the sender and the receiver using DCCP-level options;

new states to support the unfreezing phase:

1. restoration of the rate or fallback to the newly computed value;
2. probing the path for a higher capacity.

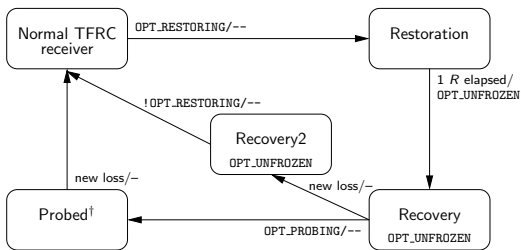
Transport Layer Disconnection Mitigation Techniques

Additional states and options needed to support freezing



Sender
Drives the restoration
process

Receiver
Ensures synchronisation

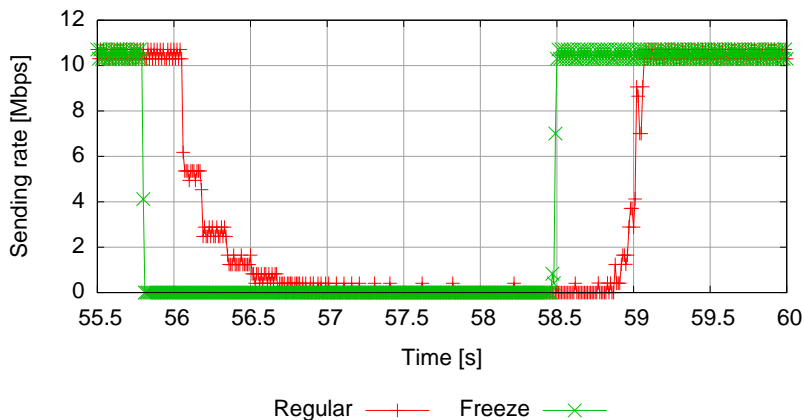


[†]When a packet is lost, the receiver computes and reports a p equivalent to the currently observed X_{recv} .

Transport Layer Disconnection Mitigation Techniques

Performance of DCCP vs. Freeze-DCCP in simulations

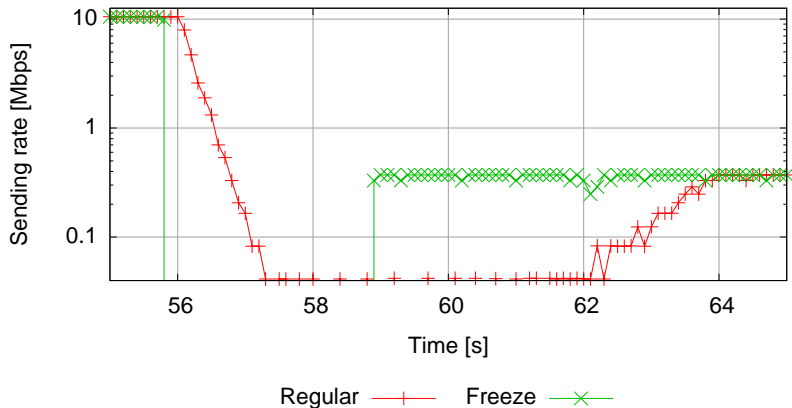
Faster rate restoration rate on similar paths (802.11b)



Transport Layer Disconnection Mitigation Techniques

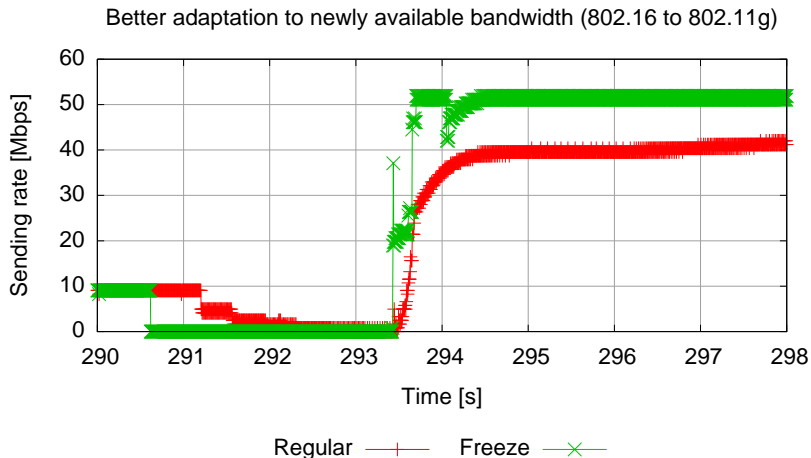
Performance of DCCP vs. Freeze-DCCP in simulations

Graceful adaptation to smaller capacities (802.11b to UMTS)



Transport Layer Disconnection Mitigation Techniques

Performance of DCCP vs. Freeze-DCCP in simulations



Though: the probing phase can still be improved.

Transport Layer Disconnection Mitigation Techniques

Performance of DCCP vs. Freeze-DCCP in simulations

| from \ to | UMTS | 802.16 | 802.11b | 802.11g |
|---|--------|----------|---------|----------|
| Packet losses (DCCP/TFRC only) | | | | |
| UMTS | 253.3 | 269.8 | 273.6 | 275.4 |
| 802.16 | 1732.3 | 1734.6 | 1734.6 | 1734.6 |
| 802.11b | 856 | 855.5 | 855.3 | 855.3 |
| 802.11g | 2470.9 | 2470.4 | 2470.2 | 2470.1 |
| Unused bandwidth [500 B packets] | | | | |
| UMTS | 50.5 | 54018.05 | 2209.5 | 92156.1 |
| 802.16 | 13.4 | 3607.9 | 9342.75 | 89328.6 |
| | 12.45 | 1827.95 | 603.05 | 4185.75 |
| 802.11b | 5 | 591.15 | 150.9 | 1520.35 |
| | 150.45 | 28314 | 2101.75 | 57970.65 |
| 802.11g | 0 | 15278 | 47.45 | 1045.05 |
| | 42.5 | 2104.3 | 943.4 | 4313 |
| | 0 | 7172.75 | 46.5 | 188.45 |

◀ Compare to analytical predictions

Transport Layer Disconnection Mitigation Techniques

Conclusion on Freeze-DCCP/TFRC

- ▶ Better network usage when/as soon as it is available;
- ▶ More flexible than Freeze-TCP:
 - ▶ can accommodate a mobile sender;
 - ▶ adapted to multiple network paths and technologies;
- ▶ Mobility-aware transport protocol well suited for real-time traffic (e.g. VoIP or video streaming).

Strong assumption: upcoming disconnections information is reliably available.

Still to be done: actual kernel implementation.

Generic Cross-Layer Design Framework

Quick outline

Expected contributions:

- ▶ **abstract description** of layers' possible states and capabilities ;
- ▶ specifications of an **external cross-layer-based optimization framework** ;
- ▶ **real implementation** of an instance of the proposed framework for **evaluation and comparison** with other proposals.

Generic Cross-Layer Design Framework

Some Cross-Layer Designs

More knowledge about the status of other elements of the stack can help optimizing the local layer.

Some examples:

Receiver-Based AutoRate signal strength measured by the receiver at the physical layer, reported in a MAC message, used by the sender to optimize its datarate;

ETX metric measured at the MAC/physical layers, used at the routing layer;

signal strength measured at the physical layer, used by mobility protocols (routing) for handoff decisions;

“Dynamic Adjustment Packet Control” multihop metrics from the routing layer, used at the application layer to adapt the video encoding strategy.

Generic Cross-Layer Design Framework

Drawbacks of Usual Cross-Layer Designs

However, most proposed cross-layer designs are

stack-intrusive solutions implemented directly into the protocol stack which can no longer work without the additional information (most of them);

ad-hoc solutions usually implemented to optimize performances in a very narrow case;

possible causes of bad interactions (e.g. RBAR with DSDV)
hence,

not easily portable or implementable in a complete system.

⇒ Need for an **external system** manipulating **abstracted information** with a **global view** of the entire stack in charge of the decision process.

Generic Cross-Layer Design Framework

Related Work

Layer details abstraction:

Layer 2 triggers

Unified Layer 2 Abstractions for Layer 3-Driven Fast Handover (RFC5184) link-related abstract details (e.g. L2-LinkUp, L2-LinkStatusChanged or L2-LinkDisconnect);

Media Independent Handovers (IEEE 802.21) interoperability between heterogeneous physical technologies.

External systems:

AODV-ST use of MAC ETX metrics to update routing table;

Fast Handovers for MIPv6 external daemon in charge of directing the L3 handover based on L2 information.

Generic Cross-Layer Design Framework

Information Abstraction

Per-layer information of interest (in progress):

Physical/MAC layer (per neighbor)

- ▶ link status;
- ▶ signal strength;
- ▶ MAC layer acknowledgments/retransmissions;
- ▶ delays;
- ▶ bandwidth, data rate;
- ▶ compound metrics (e.g. ETX or ETT).

Routing layer (per network)

- ▶ metric/cost of forwarding along a given route;
- ▶ existence of parallel routes.

Transport layer (per end-to-end network path)

- ▶ round trip time, jitter;
- ▶ achievable throughput.

Application (per socket)

- ▶ data rate (both ways);
- ▶ compression, encoding, ...

Generic Cross-Layer Design Framework

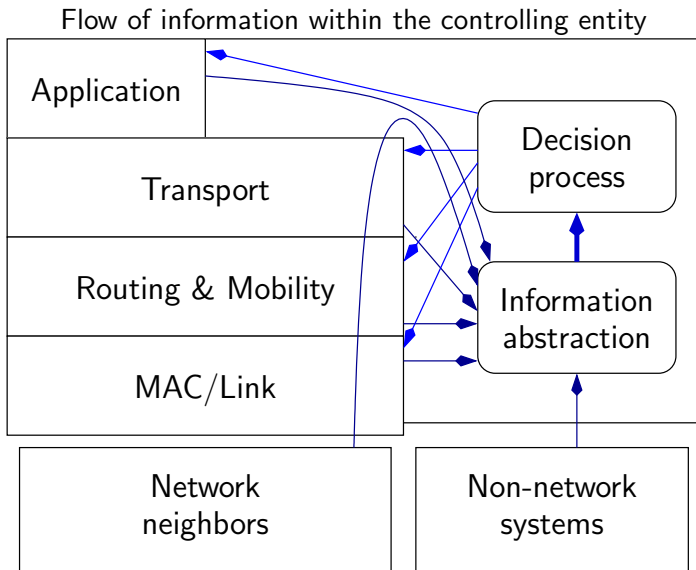
Out-of stack System

Flow of information within the controlling entity

1. Acquisition of information;
 - ▶ layer-specific
 - ▶ signal strengths,
 - ▶ end-to-end path throughputs,
 - ▶ route metrics, ...
 - ▶ non network-related information
 - ▶ geographical location,
 - ▶ machine learning predictions, ...
2. Conversion into **abstract information**;
3. **Optimization-oriented** decisions with global information;
4. **Information/instruction passing** to the desired layers.
 - ▶ freeze if the **network path** will be down,
 - ▶ change the video encoding if the transport reports a **drop in throughput**.

Generic Cross-Layer Design Framework

Out-of stack System

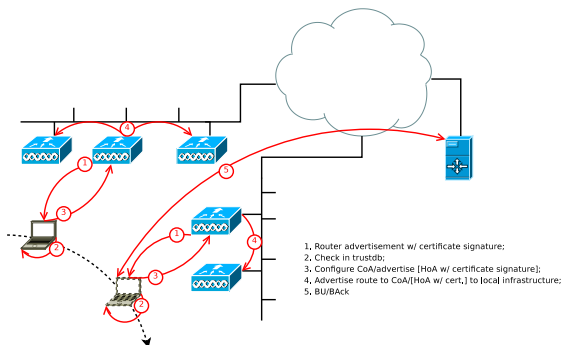


Future Work

Trust for Routing in Partially Disconnected Networks

Need for decentralized trusted authentication at the routing layer

- ▶ Can an equipment presenting itself as part of the infrastructure be trusted as such?
- ▶ How to use the HoA of a mobile node/router in a disconnected environment?
- ▶ How to avoid spoofing/route poisoning?



Future Work

Consideration for Demonstration Applications

Discovery and used of of available services in the vicinity of the station

- ▶ ITS: traffic, road conditions, weather ahead;
- ▶ Pocket Mobility: bus timetables, shop stock availability;
- ▶ Home or generic automation: detection of the environment, capabilities and statuses, instruction/report exchanges.

Administrative Information

Publications

- [1] Olivier Mehani and Roksana Boreli.

Adapting TFRC to mobile networks with frequent disconnections.

In CoNEXT 2009, 4th ACM Int'l Conference on emerging Networking EXperiments and Technologies, Student Workshop, Madrid, Spain.

- [2] Olivier Mehani, Roksana Boreli, and Thierry Ernst.

Analysis of TFRC in disconnected scenarios and performance improvements with Freeze-DCCP.

In MobiArch'09, 4th ACM Int'l Workshop on Mobility in the Evolving Internet Architecture [submitted], Kraków, Poland.

Administrative Information

Academic Courses

Courses completion:

Advanced Networking (TELE9756) 6 UNSW credits, 33 contact hours, current result: 45%, final exam postponed to S2 2009 (worth 55%);

Nicta Short Courses 2 UNSW credits, 21 contact hours each,

- ▶ Network Simulation, assessment result: 95%;
- ▶ Network Analysis, result pending;

Security Engineering (COMP9441) 6 UNSW credits, 60 contact hours, final examination in June.

Universities requirements:

ENSMP 21/60 hours, 114 currently pending;

UNSW 2/18 credits, 14 currently pending.

Administrative Information

Tentative Completion Schedule

April-June 2009 (Nicta)

- ▶ Freeze-DCCP implementation & experimental evaluation;
- ▶ Layer information availability & needs;
- ▶ Cross-Layer framework abstractions specification;
- ▶ Cross-Layer framework initial implementation;

July-December 2009 (Inria) ITS applications

- ▶ Cross-Layer integration into the vehicular network;
- ▶ Infotainment-based experiments of Freeze-DCCP;
- ▶ Trusted authentication framework (VANET, road-side infrastructure);

January-March 2010 Pocket mobility/Ambient Intelligence

- ▶ Adaptation of the previous work to portable devices (CAMP project);
- ▶ Service discovery system (based on cross-layer triggers);
- ▶ Pervasive network applications demonstrators.

April-September 2010 Thesis writing;

September 2010 Thesis submission.

Discussion

Thanks

Questions ?