Improved end-to-end connectivity for energy constrained and challenged environments

Partners: Nokia, NSN, Aalto/ComNet, Aalto/CSE, HU, VTT

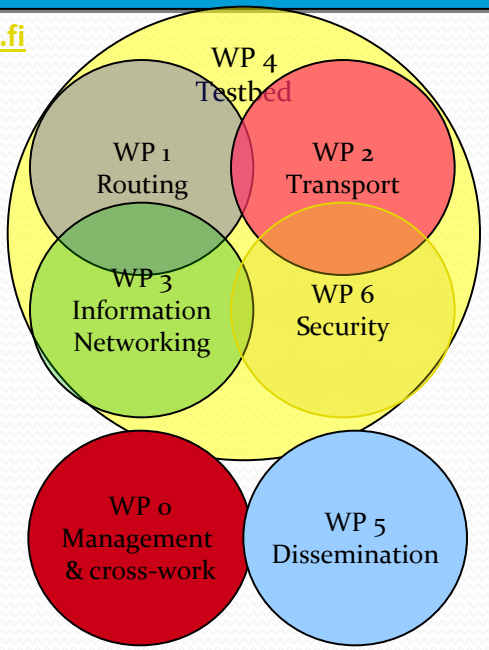
TIVIT SEMINAR 12.4.2011, Johanna Nieminen

Tivit Future Internet Program 2008 - 2013

Vision: Future Internet = a mission critical backbone of global information society

Mission: Enhance the Internet technology and ecology as a *platform for innovation* while providing strong governance over the use of the network resources and information

4 yr Strategic Research Agenda: www.futureinternet.fi



Phase 2 Partners (6/2009 – 3/2011):
CSC – IT Center for Science, Cybercube, F-Secure, Ericsson, Nokia, Nokia Siemens Networks, Stonesoft, TeliaSonera Finland, Aalto University, Universities of Helsinki, Jyväskylä and Turku, Tampere University of Technology, VTT Technical Research Centre of Finland, Tivit

Activities in WP2, phase 2

- Task 1: Models for Energy-Aware Internet Communication
  - Energy aware communication and services, energy and power control, holistic energy management
- Task 2: Communication in Challenged Environments
  - DTN Simulator Infrastructure, Industrial Applications, Future Internet Transport Protocol, Cross-layer support and reliable transport, Management of control information, PBRM concept, mechanisms and policies

Results highlights in Task 1

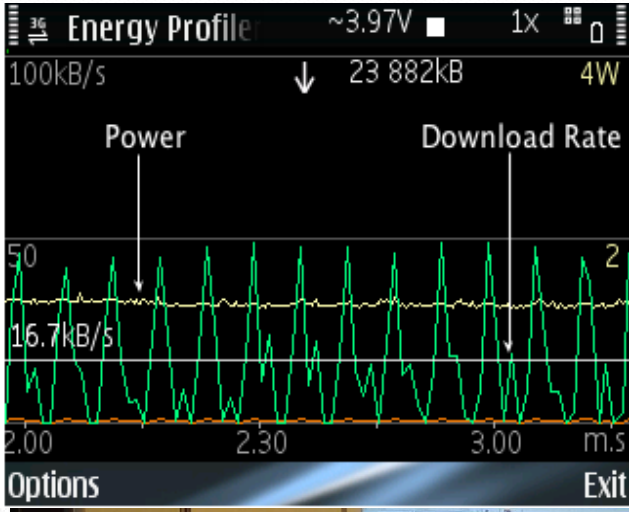
- Energy modeling (Nokia/CSE/ComNet)
- Holistic device energy management (Nokia/CSE/ComNet)
- Energy and power control (VTT)
- Proxy-based solution for energy-efficient web access (ComNet)

Energy modeling

- Increasing gap between
  - Mobile phone battery capacity and
  - Energy consumption by typical usage
- Need to understand the energy consumption
  - Measurements
  - Modeling
- Application areas
  - Energy-aware protocols and services
  - Smarter device power management

Methodology

- Power measurements
  - Software
  - Hardware
- Power modeling
  - Straightforward and practical models
  - Only significant energy savings make a difference for QoE
- Apply models
  - Energy aware application
  - Energy-efficient protocols



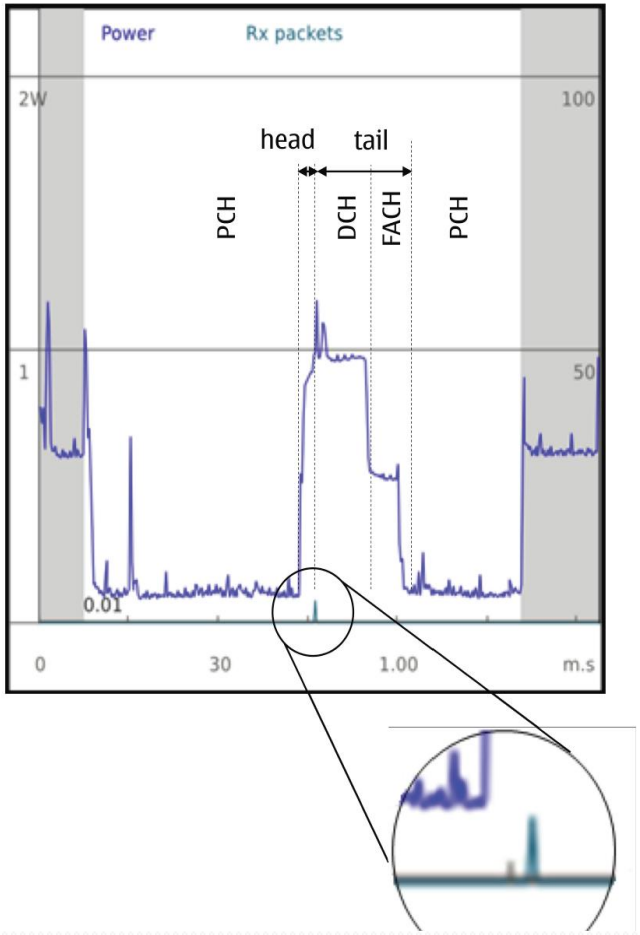
Key results

- Modeling and measurements
  - Y. Xiao, R. Bhaumik, Z. Yang, M. Siekkinen, P. Savolainen, and A. Ylä-Jääski. A System-level Model for Runtime Power Estimation on Mobile Devices. In IEEE/ACM GreenCom 2010.
  - Y. Xiao, P. Savolainen, A. Karppanen, M. Siekkinen, and A. Ylä-Jääski. Practical power modeling of data transmission over 802.11g for wireless applications. In ACM e-Energy 2010. (Best paper award)
  - P. Miranda, M. Siekkinen, H. Waris. TLS and Energy Consumption On a Mobile Device: A Measurement Study. To appear in IEEE ISCC 2011.
- Optimization
  - Y. Xiao, M. Siekkinen, and A. Ylä-Jääski. Framework for energy-aware lossless compression in mobile services: the case of E-mail. In IEEE ICC 2010.
  - A. Nazir Raja, Z. Jin, and M. Siekkinen. Energy Efficient Client-centric Shaping of Multi-flow TCP Traffic. In Proceedings of the 2010 IEEE/ACM GreenCom 2010.
  - R. Sri Kalyanaraman, Y. Xiao, A. Ylä-Jääski. Network Prediction for Energy-aware Transmission in Mobile Applications. International Journal on Advances in Telecommunications. Sept. 2010.

Holistic device energy management

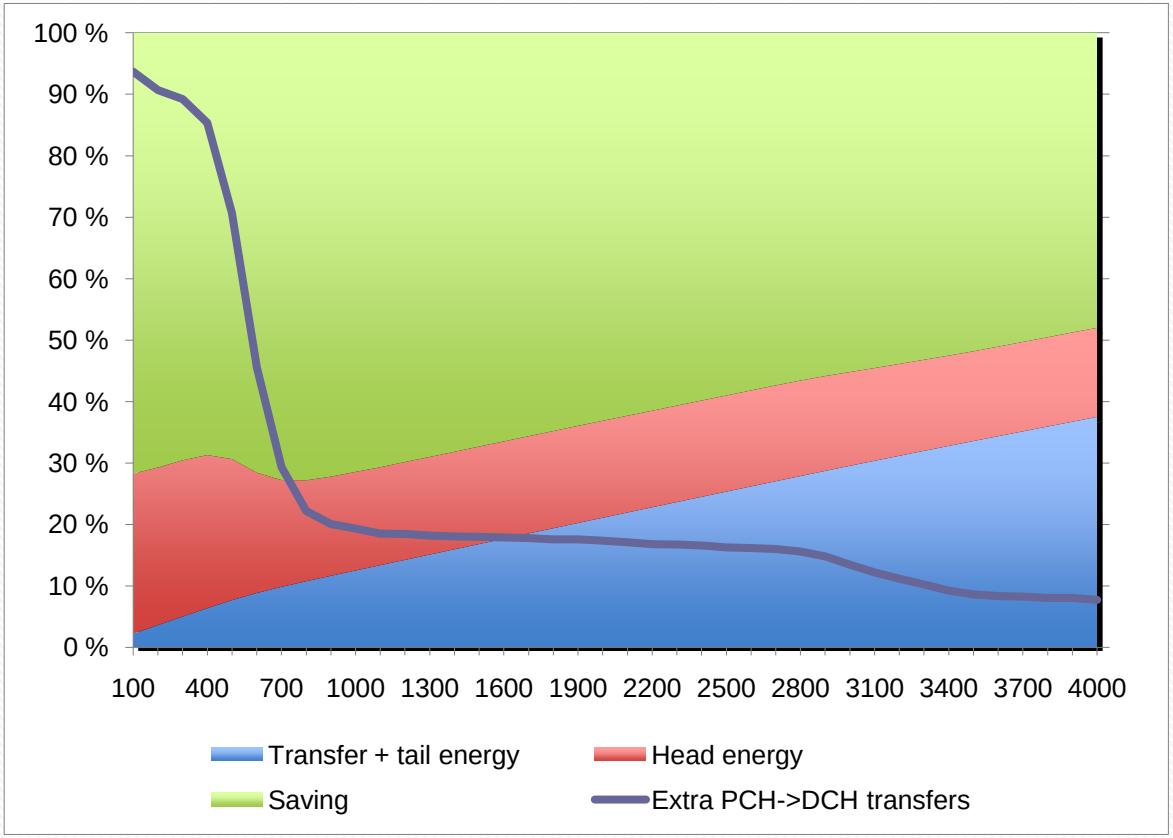
- Unwanted network traffic is a problem for devices with always-online cellular connection.
- Sporadic data traffic causes extra energy consumption due to
  - Cellular modem that is active during the data transfer
  - CPU that is processing the IP protocols, even if discarding the IP packet
- Consumes **over 20%** of energy of an otherwise idle phone.
- The effect can be alleviated with Fast Dormancy: dropping cellular data connection more aggressively using shorter timeouts.
  - in idle mode a short static timeout may decrease the wasted energy by 73 % and only cause 22 % increase in the amount of signalling needed.

Example result



- Example shows the arrival of a single ICMP ECHO packet over 3G cellular data connection.
- Measurement made in Nokia N900

Simulation results



- Required energy with different cellular timeouts (ms)

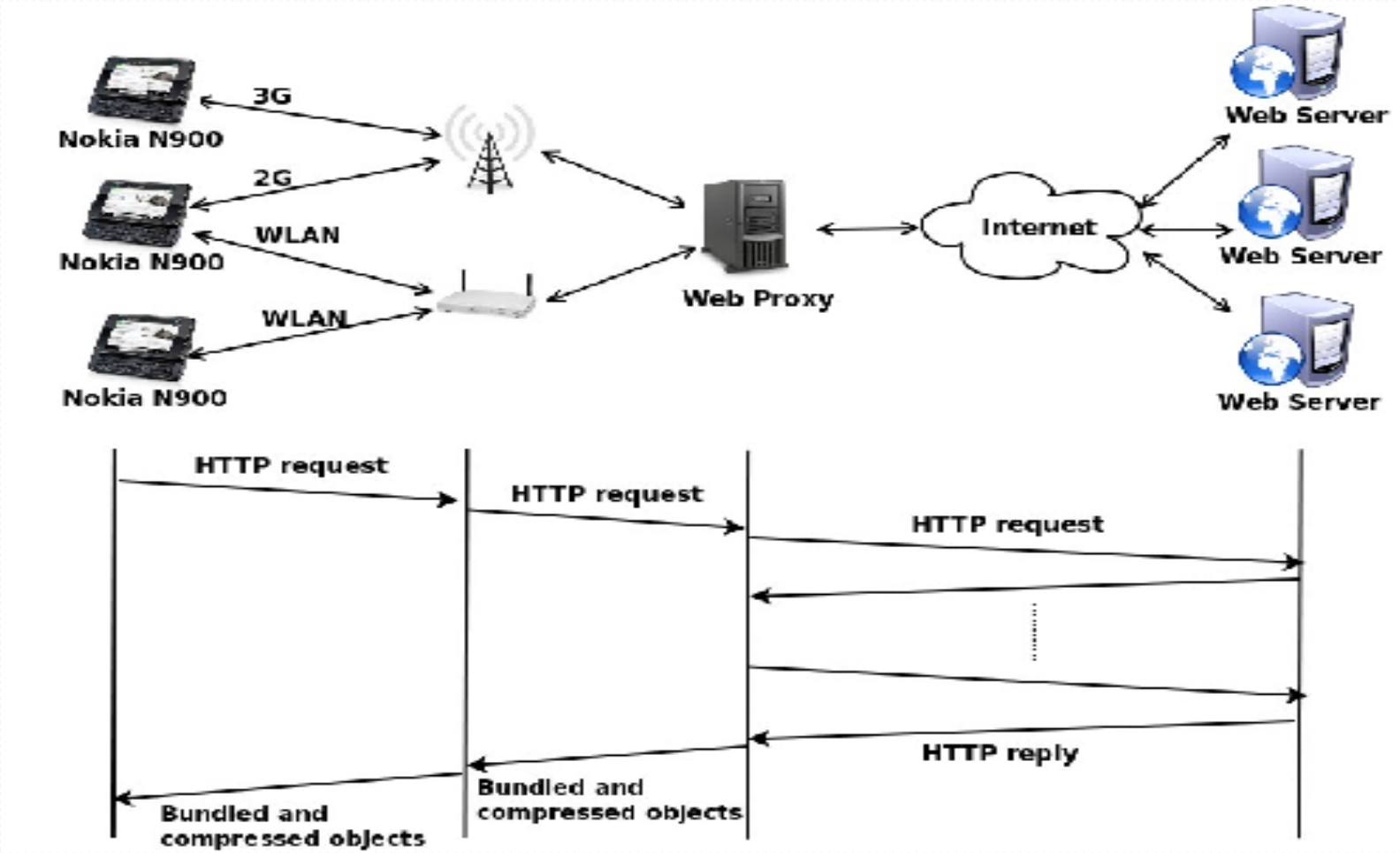
Energy and power control

- VTT has studied and developed new solutions to accomplish energy savings in LTE-A
  - How to support DRX when a mobile is attached to a relay BS?
- Publications:
  - Kostas Pentikousis, "In search of energy-efficient mobile networking," IEEE Communications Magazine, vol.48, no.1, pp.95-103, January 2010. [DA2.1.13]
  - Kaisa Kujanpää and Petteri Mannersalo, "A note on DRX power saving in LTE-A relay networks", Technical report, Dec. 2010.
  - Mikko Majanen, Numbat WiMAX patch to OMNeT++ v. 4.0 (open source)

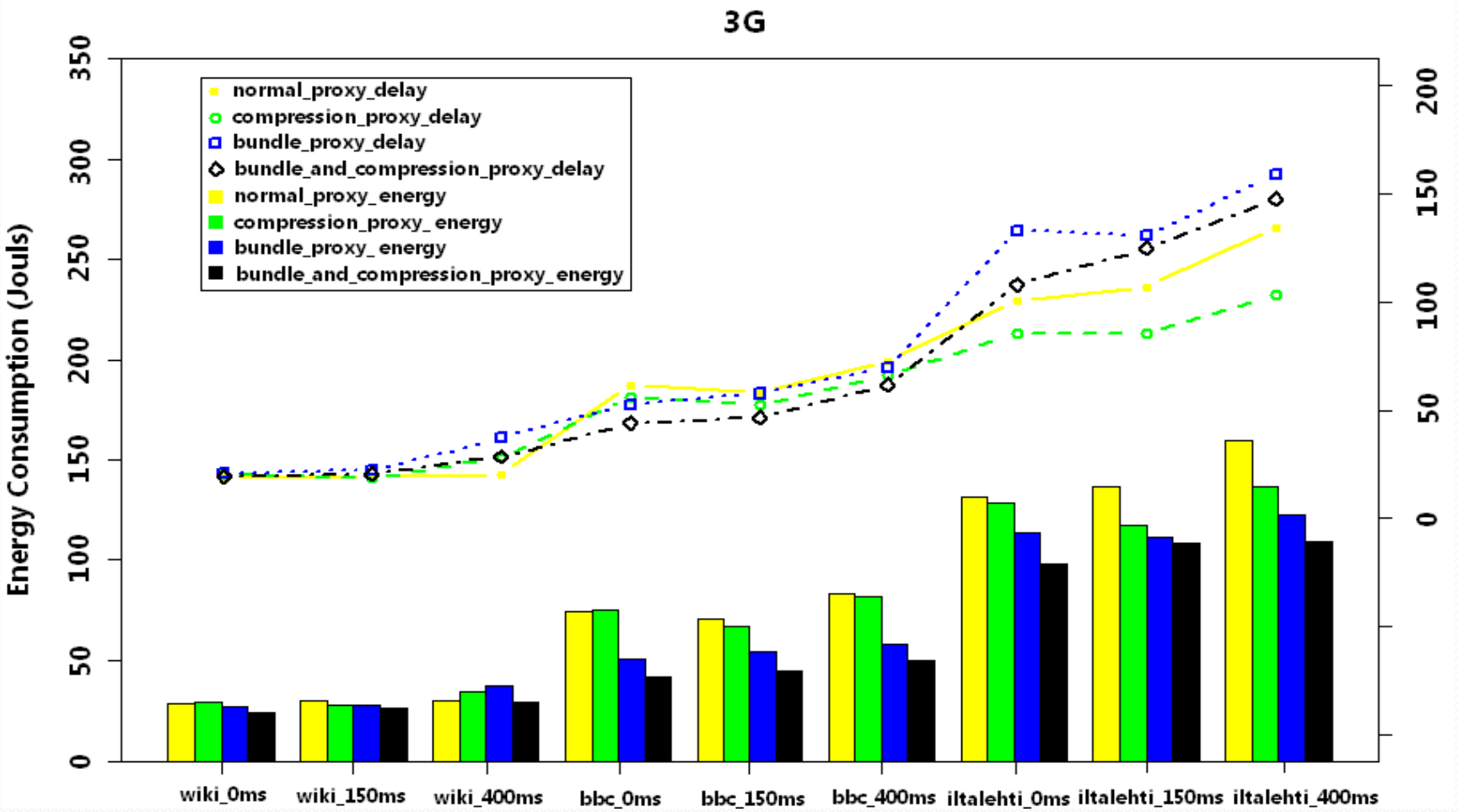
Proxy-based solution for energy-efficient web access

- ComNet has designed a proxy-based architecture for web access
  - Generic and transparent solution
  - Independent of browsers
  - Bundling and compression to decrease delivery time
  - Minimizing the side-affect of TCP throughput

The architecture applies simplified data exchange process to fetch bundled and compressed web content from web proxy after all the embedded objects are fetched by the web proxy



Results in 3G



Results highlights in Task 2

- DTN in Mines (Nokia/ComNet/Cybercube)
- Cross-layer support and reliable transport (UH)
- Management of control information (VTT)
- Policy-Based Resource Management (NSN)

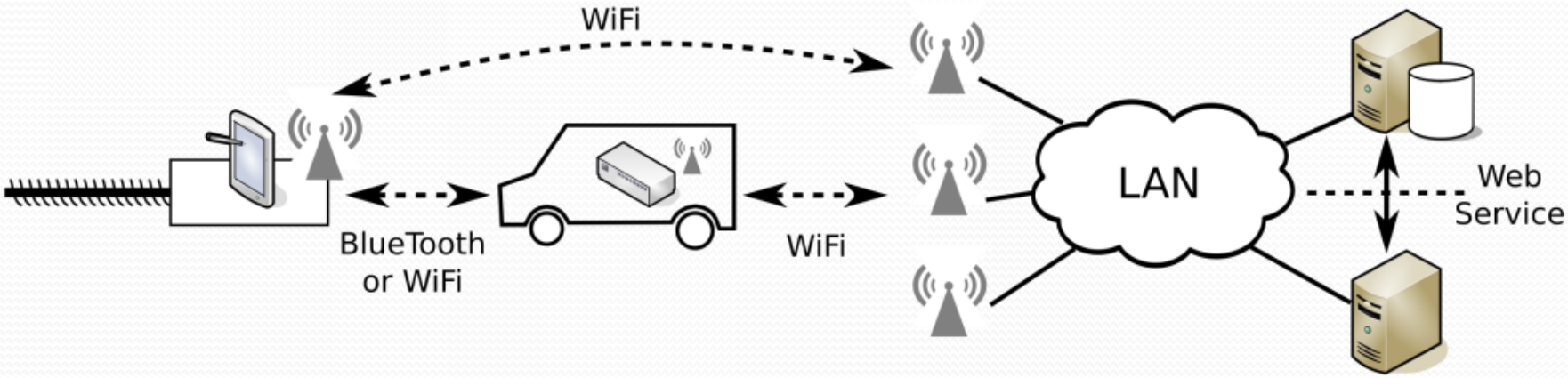
DTN in Mines

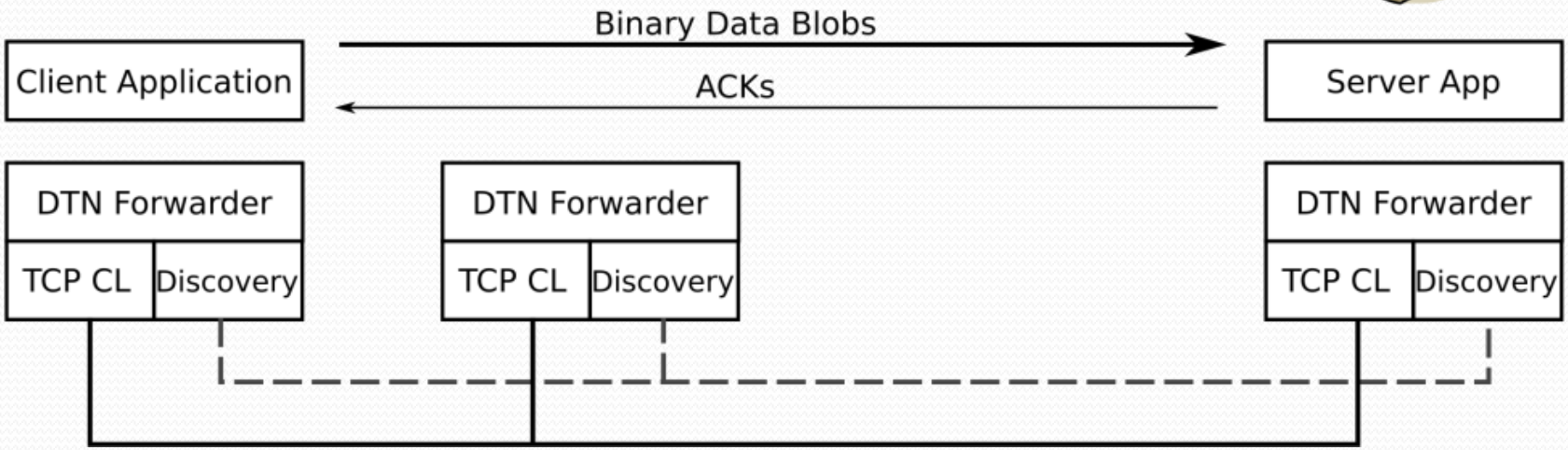
- 3000-4000 operating underground mines worldwide
  - Lifetime of a few years to tens of years
  - Ten to hundreds of pieces of equipment per mine
  - Personnel operating in two to three shifts
- Development and production phases
  - Work cycles with specialized equipment
  - Tens of locations in various phases and stages
- Coordinating the fleet of equipment and personnel requires a robust communications in a challenging environment.

DTN in Mines

- Physical movement of people and equipment creates space-time paths – paths that are constructed from multiple hops over time.
- Classic networking protocols and techniques cannot exploit space-time paths, but store-carry-forward networking can.
- ComNet/Nokia is building a data communication system for mines based on physically carrying and exchanging data between trucks and mobile phones.

DTN in Mines


WiFi
BlueTooth
or WiFi
WiFi
LAN
Web
Service


Binary Data Blobs
Client Application
ACKs
Server App
DTN Forwarder
TCP CL
Discovery
DTN Forwarder
TCP CL
Discovery
DTN Forwarder
TCP CL
Discovery

Cross-layer support and reliable transport

- Design, implementation and experimental work on
  - approaches exploiting cross-layer information for more efficient congestion control in transport protocols
  - Novel mechanisms for router queue management and monitoring as well as capacity estimation with cross-layer indications
  - link-layer assisted mechanism for distinguishing bit-error related losses from congestion related losses

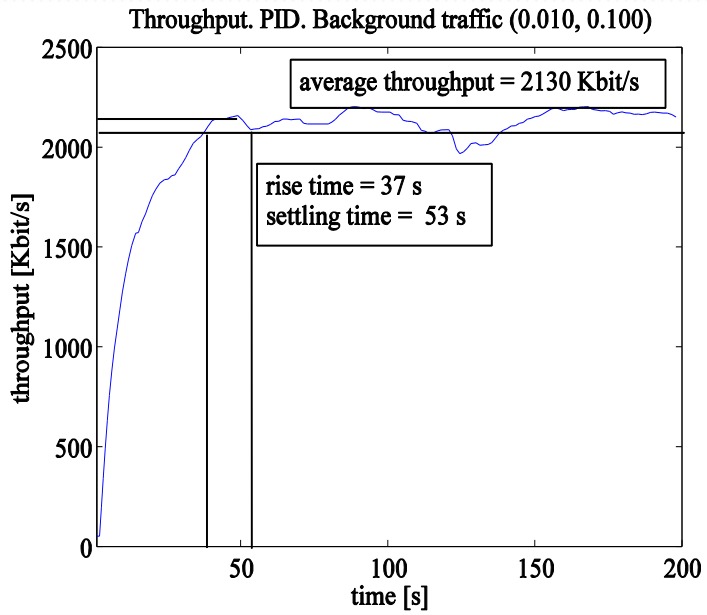
Key results

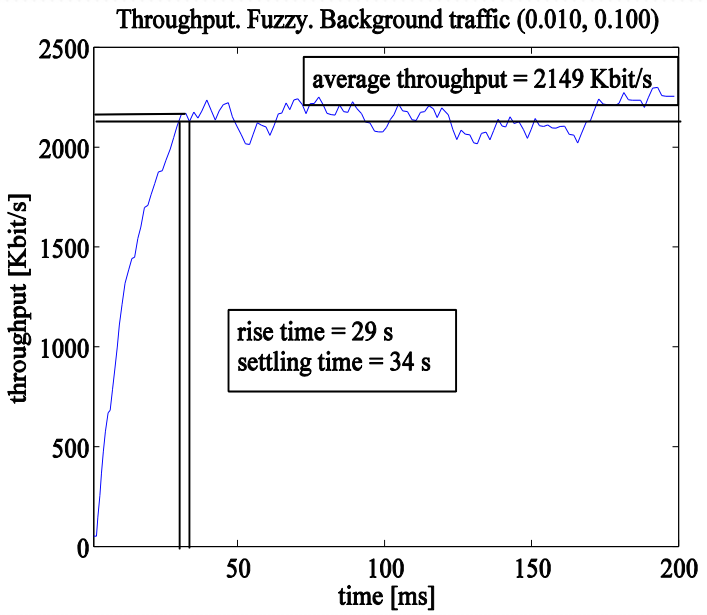
- **Thesis work:**
  - L. Daniel. "Cross-layer Assisted TCP Algorithms for Vertical Handoff", Doctoral dissertation, University of Helsinki, Department of Computer Science Series of Publication A. Report A-2010-6 - URN:ISSN:1238-8645, November 2010.
- **Standards Contributions:**
  - I. Jarvinen, M. Kojo. "Using TCP Selective Acknowledgement (SACK) Information to Determine Duplicate Acknowledgements for Loss Recovery Initiation", Internet-Draft (draft-ietf-tcpm-sack-recovery-entry-01.txt), work-in-progress
  - E. Blanton, M. Allman, I. Jarvinen, M. Kojo. "A Conservative Selective Acknowledgment (SACK)-based Loss Recovery Algorithm for TCP", Internet-draft (draft-blanton-tcpm-3517bis-00.txt), work-in-progress.

Management of control information

- VTT has developed and simulated a PID (Proportional, Integral, Derivative) and fuzzy control systems
  - regulates packet sizes of User Datagram Protocol (UDP) based traffic on WLANs according to prevailing network conditions such as delay
- Several publications produced

Throughput results





- Figures above present throughput as a function of time, when the packet size was adjusted by the fuzzy and PID controller and the surrounding nodes transmit packets at random intervals i, where i ∈ [0.010 s, 0.010 s]. With the fuzzy controller average throughput is a bit higher and the rise and settling time are shorter than with the PID controller.

Policy-Based Resource Management (PBRM)

- NSN PBRM concept
  - PBRM realization in real life environment, e.g. in 3GPP networks
  - Using PBRM to enable WLAN offload from cellular networks
  - Traffic steering between different radio accesses with PBRM
- In Phase 3, the work on PBRM concept will be continued under WP1
  - PBRM implementation will be part of WP1 show case