

IMPROVED END-TO- END CONNECTIVITY FOR ENERGY CONSTRAINED AND CHALLENGED ENVIRONMENTS

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

Future Internet SHOK preconference 30.5.2012

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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



Partners:

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 DURING THE PROGRAMME

◉ Task 1: E2E User Experience in mobile

- Energy aware communication and services, energy and power control, holistic energy management, Future Internet Transport Protocol, Cross-layer support and reliable transport

◉ Task 2: E2E energy efficient connectivity of sensors with the Internet

- Configuring and connecting sensors with the Internet, comparing different low-power radio technologies

◉ Task 3: Communication in Challenged Environments

- DTN Simulator Infrastructure, Industrial Applications, Management of control information, PBRM concept, mechanisms and policies

RESULTS HIGHLIGHTS

- ◎ **Major achievements with clear business potential**

- IPv6 enabled Bluetooth Low Energy Sensors
- PBRM concept
- Home gateways
- Web proxy

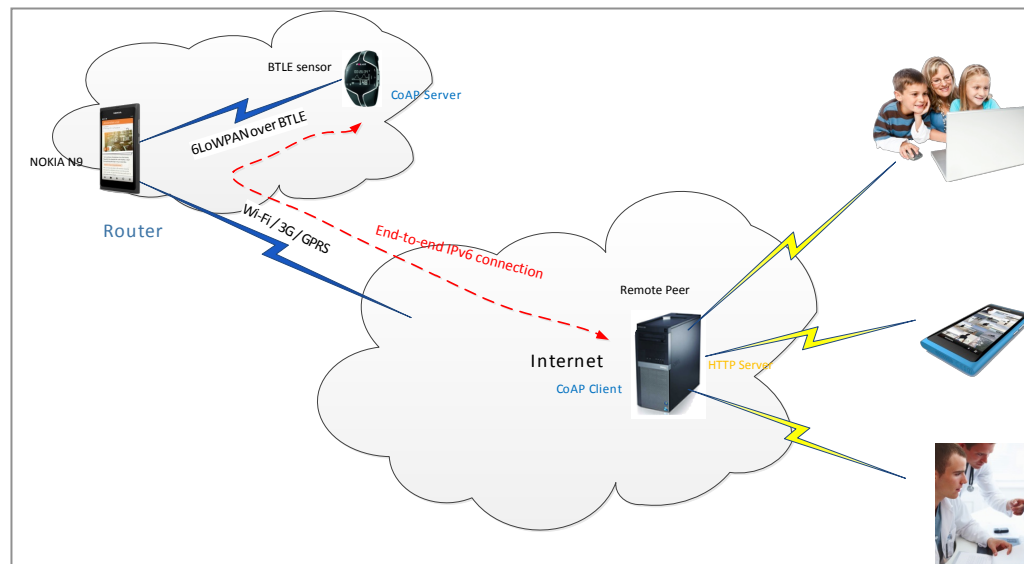
- ◎ **Other key results, business potential in longer term**

- Energy models and measurements
- DTN infrastructure
- TCP protocol optimizations

MAJOR ACHIEVEMENTS

IPV6 ENABLED BLUETOOTH LOW ENERGY SENSORS (NOKIA)

- ◉ **Future vision:** billions of sensors that will be networked and should be connected with the IP-based networks.
- ◉ **Developed a solution** for transmitting *IPv6 packets over Bluetooth Low Energy to/from sensors* using a mobile device as a gateway. The solution has been prototyped using a real heart-rate belt, N9 mobile device and web servers.
- ◉ **Standardization** of the solution in the IETF has progressed fast.
- ◉ **Business potential:** The results can be utilized by sensor and accessory vendors, mobile device vendors and home gateway vendors. The solution can be seen as a catalyst for a new end-to-end IPv6 capable sensor ecosystem and flexible application development.



POLICY-BASED RESOURCE MANAGEMENT, PBRM (NSN)

NSN PBRM concept

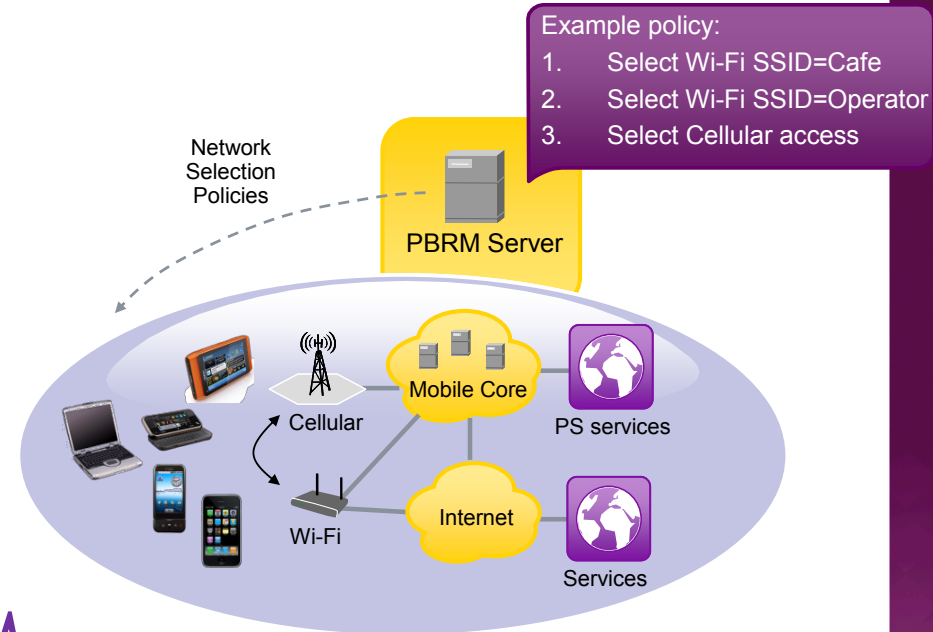
PBRM realization in real life environment, e.g. in 3GPP networks

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 has been continued under WP1

PBRM implementation is part of WP1 show case

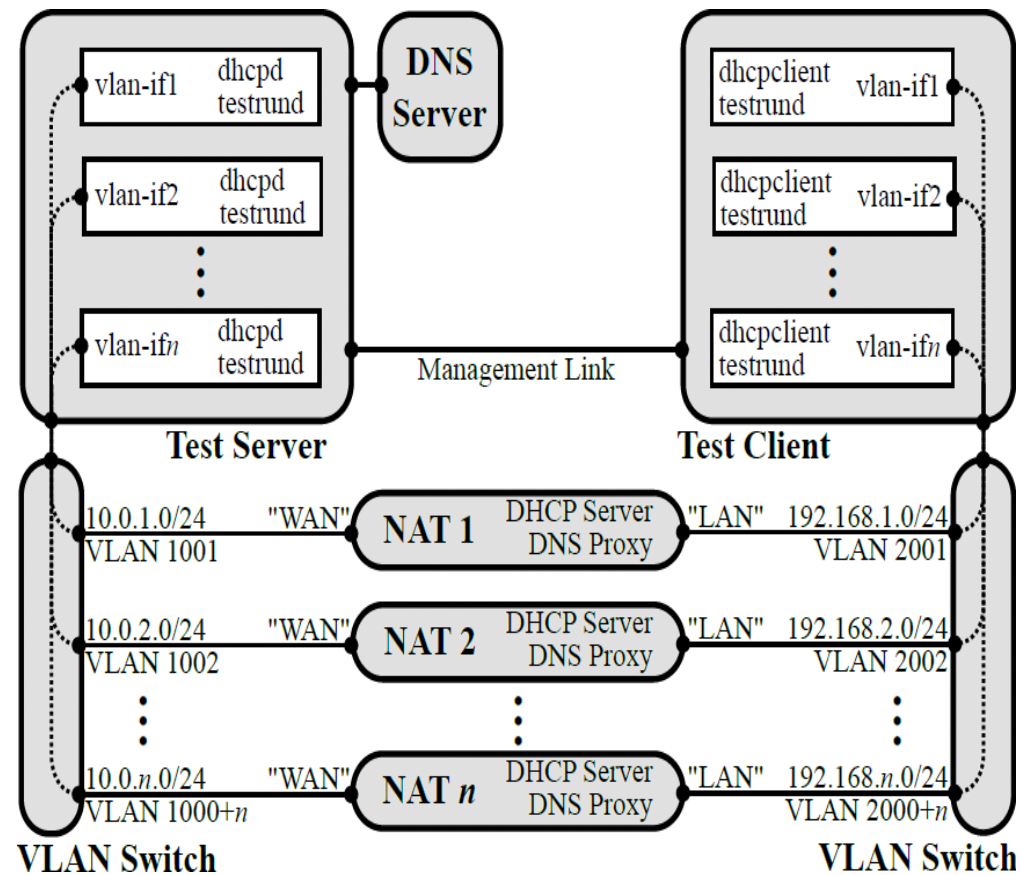


CROSS-LAYER SUPPORT AND RELIABLE TRANSPORT (UH)

- ◉ **Design, implementation and experimental work on**
 - Approaches exploiting cross-layer information and network capacity estimation for more efficient congestion control in transport protocols
 - Novel mechanisms for improved processing and energy efficiency with TCP
- ◉ **Standards contributions to IETF on TCP congestion control algorithms**
 - Impact: the algorithms are implemented in TCP/IP stacks by all major OS vendors for Internet wide deployment

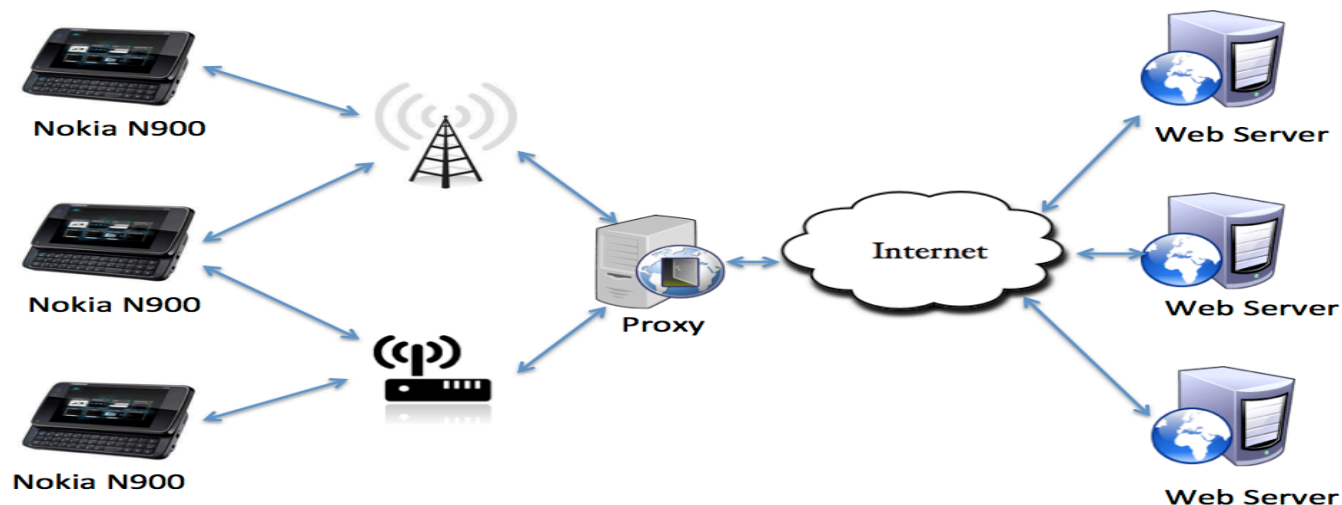
HOME GATEWAY TESTBED FOR NAT CHARACTERISTICS EXPERIMENTATION (UH)

- Unique in the world
- Wifi access-points, DSL and cable modems
- Around 100+ devices once all devices connected
- Test software implemented to test various NAT characteristics

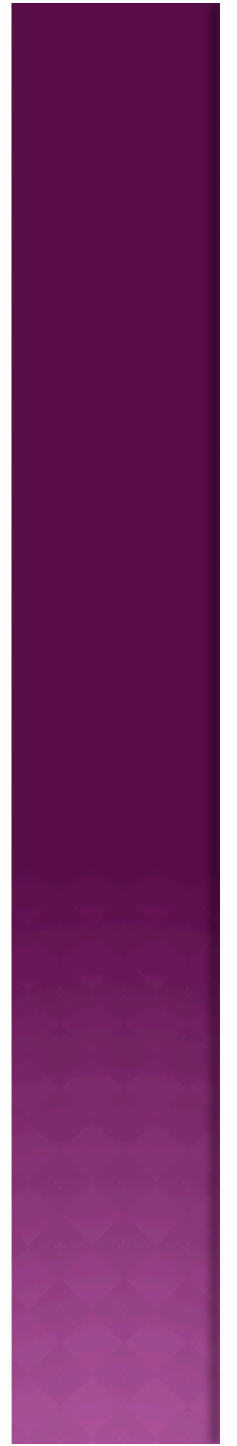


WEB PROXY (AALTO/COMNET)

- ◉ **Web proxy:** 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
- ◉ See details in Jukka Manner's presentation



OTHER KEY RESULTS



ENERGY MODELING AND OPTIMIZATION IN MOBILE COMPUTING (AALTO/CSE, NOKIA)

- ◉ Motivation

- Increasing gap between smartphone battery capacity and energy consumption by typical usage
- New low-power radios emerged that will enable new applications
 - e.g. Bluetooth Low Energy

- ◉ Approach

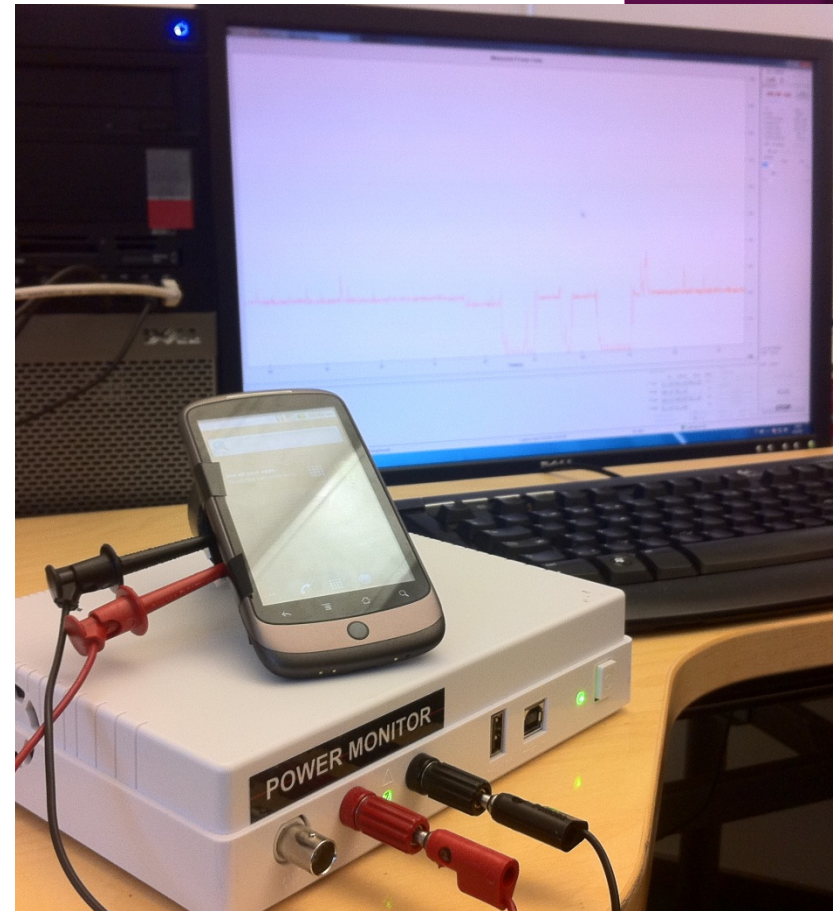
- First understand the energy consumption through measurements and modeling
- Then optimize the energy consumption

- ◉ Main achievements

- Measurement studies of energy consumption of devices, protocols, and services
- Developed deterministic energy models for wireless communication (Wi-Fi, 3G, Bluetooth Low Energy, 802.15.4) and linear model for mobile devices
- Developed energy-efficient protocols and services, and power management solutions for mobile devices
- Practical implementation for estimating the bandwidth of wireless end-to-end communication channel
 - The bandwidth estimation has been tested using virtual cloud servers in three continents (Europe, US, Asia)

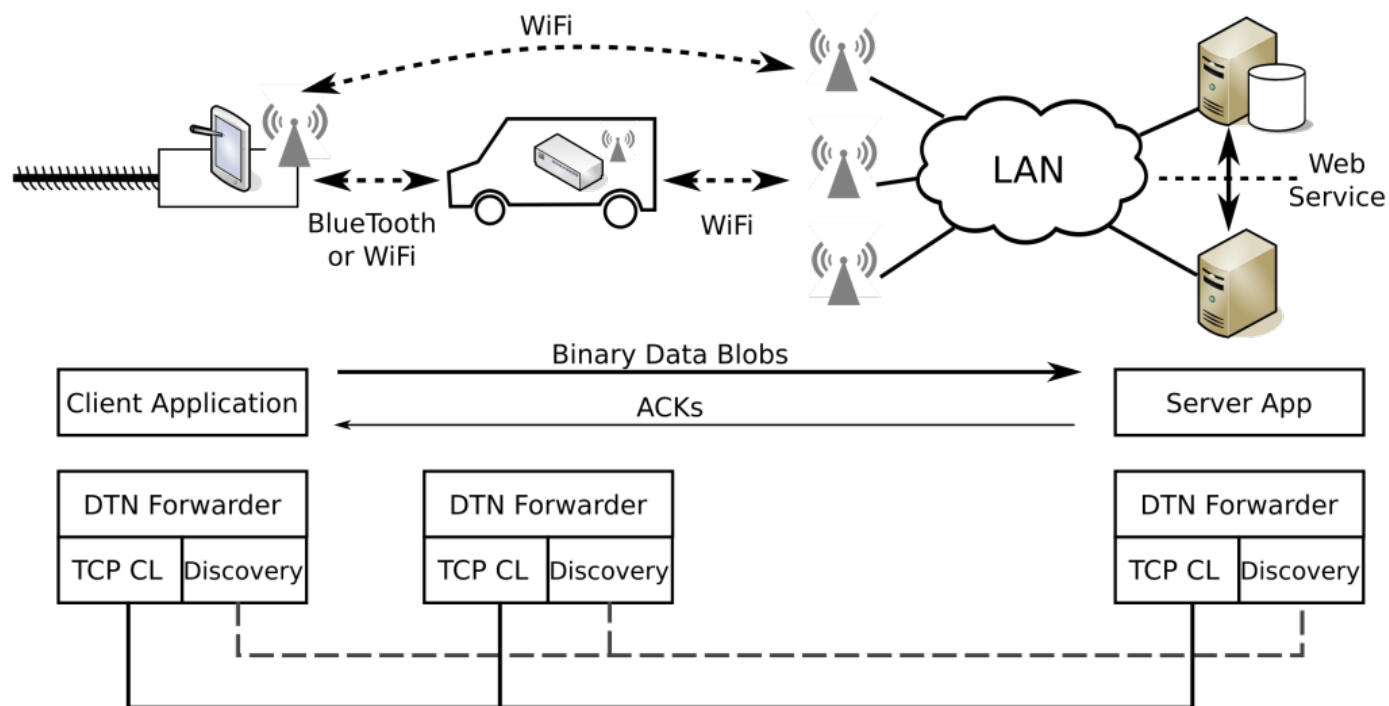
RESULTS IN NUMBERS

- ◉ 14 conference papers
 - One best paper award (ACM e-energy)
- ◉ Two journal papers
- ◉ One Ph.D. thesis
- ◉ Four M.Sc. thesis
- ◉ Spin-off project funded by the Finnish Academy



DTN IN MINES (NOKIA, AALTO/COMNET)

- Data communication system for mines based on physically carrying and exchanging data between trucks and mobile phones
- Fragmentation model development in multi-hop case and experimentation with the Kemi mine prototype



FLOW LENGTH DEPENDENT CONGESTION CONTROL (AALTO/COMNET)

- Since there are many (90th percentile) short flows in the Internet
- **Improves E2E user experience**
 - Users perceive delay in short flow transfers more disruptive/annoying than in long flows
- **Saves Energy** in wireless mobile devices
 - Finish flows faster and close radio which drains significant amount of energy
- **Improves the transfer time** of short flows
- See details in Jukka Manner's presentation