Mobility:
An Inside Perspective from Telecom Operators

Pablo Vidales and Calicrates Policroniades

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Deutsche Telekom Laboratories
telenor

Introduction

Lecturers.
R&D scientific members of large Telecom Operators.

PABLO VIDALES, PhD

- Sr. Research Scientist at Deutsche Telekom Laboratories
- Computer Lab, University of Cambridge
- Over 20 international scientific publications, five patents
- Research areas: Wireless Systems, Mobility, Mobile solutions
- Working on mobile systems for the past eight years

DEUTSCHE TELEKOM LABS

- Founded in 2005 in Berlin
- 30 researchers, 150 total staff

CALICRATES POLICRONIADES, PhD

- Sr. Research Scientist at “Products and Markets” division, Telenor R&I
- Computer Lab, University of Cambridge
- Data abstractions and data access strategies for mobile environments
- Research areas: Mobile search, mobile solutions, mobile applications
- Working on mobile solutions for the past eight years

TELENOR R&I

- Celebrating 40 years
- 200 research staff members in 4 campuses

Rules of the house.

- Tutorial content in 7 topics
  - Part One (80 min) – Dr. Pablo Vidales (Deutsche Telekom Labs)
  - Coffee break (20 min)
  - Part Two (80 min) – Dr. Calicrates Policroniades (Telenor R&I)
- Don't ask in order to ask (let's interact)
- Swimming suits are not allow in the room (wait to go to the beach)
- We promise to finish on time and make it worth it

Objectives.
An inside into Telecom Operators.

(b) To described a proposal to enable mobility in access networks.

(a) To define mobility in future communications systems.

(c) To present some R&D cases related to mobile services.

Tutorial content.

PART ONE

- Basic concepts
- Enabling mobility
- User perception of mobility

PART TWO

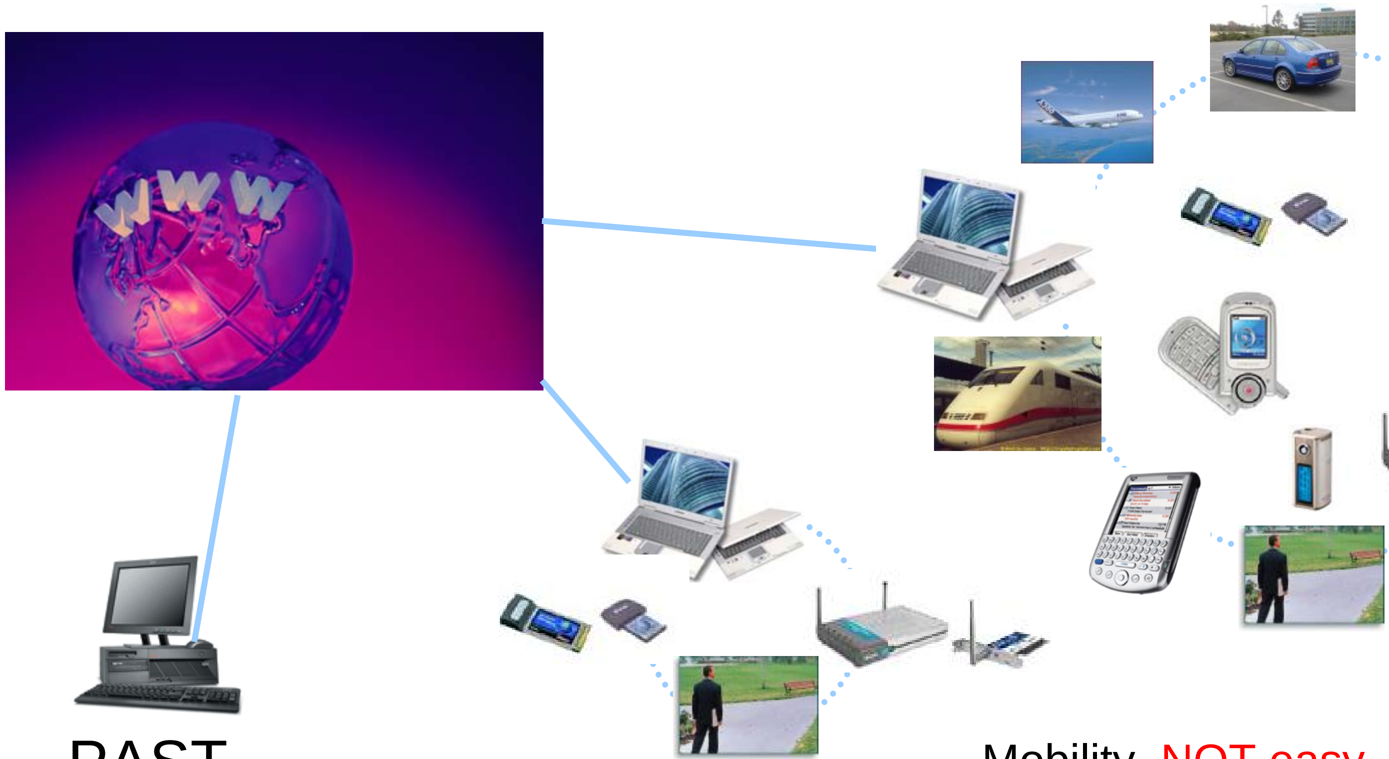
- Social Networks/Data management
- Connected Objects
- Mobile search and Ads
- Open innovation Platforms and Testbeds

Movement is eternal…

Physics, Aristotle

Mobility.
Basic concepts.

Evolution.
Devices.



IEEE 802.20
UMTS
HIPERLAN
Bluetooth
Satellite
IEEE 802.11a
IEEE 802.11b
IEEE 802.11g
GSM/GPRS
HSDPA

FUTURE

PAST

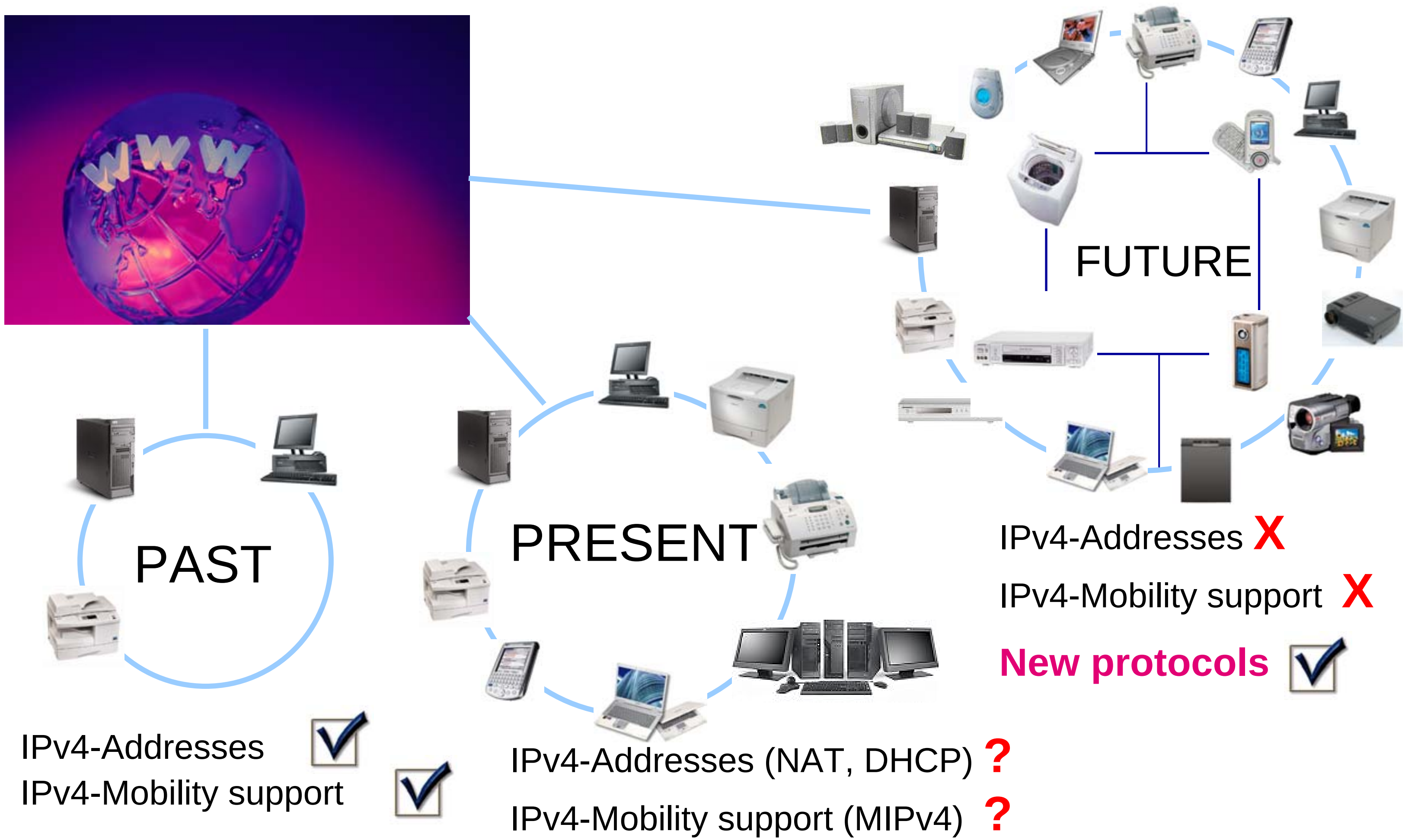
Mobility, none
Networking complexity, none

PRESENT

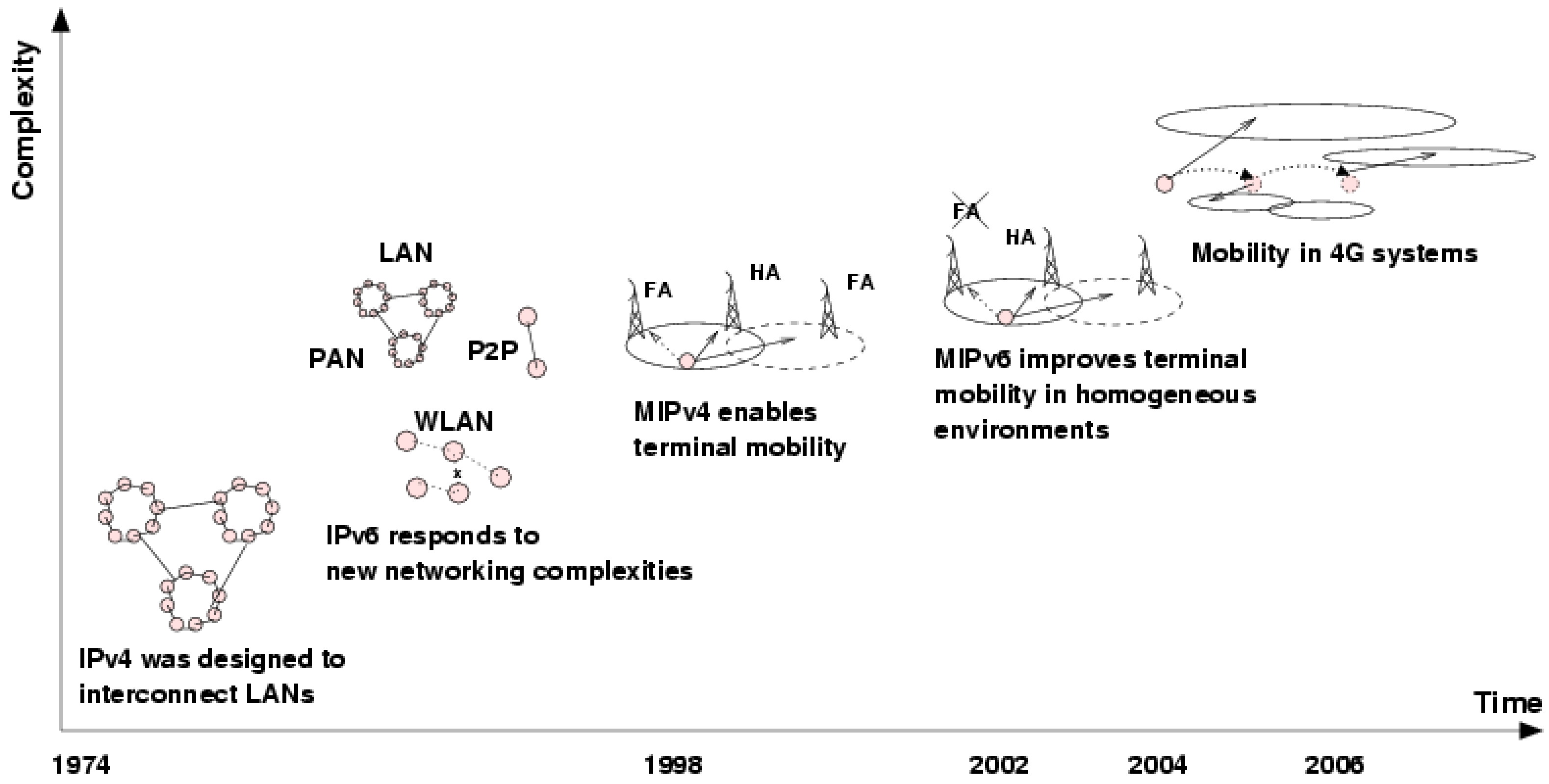
Mobility, easy?
Networking complexity, easy?

Mobility, NOT easy
Networking complexity NOT easy

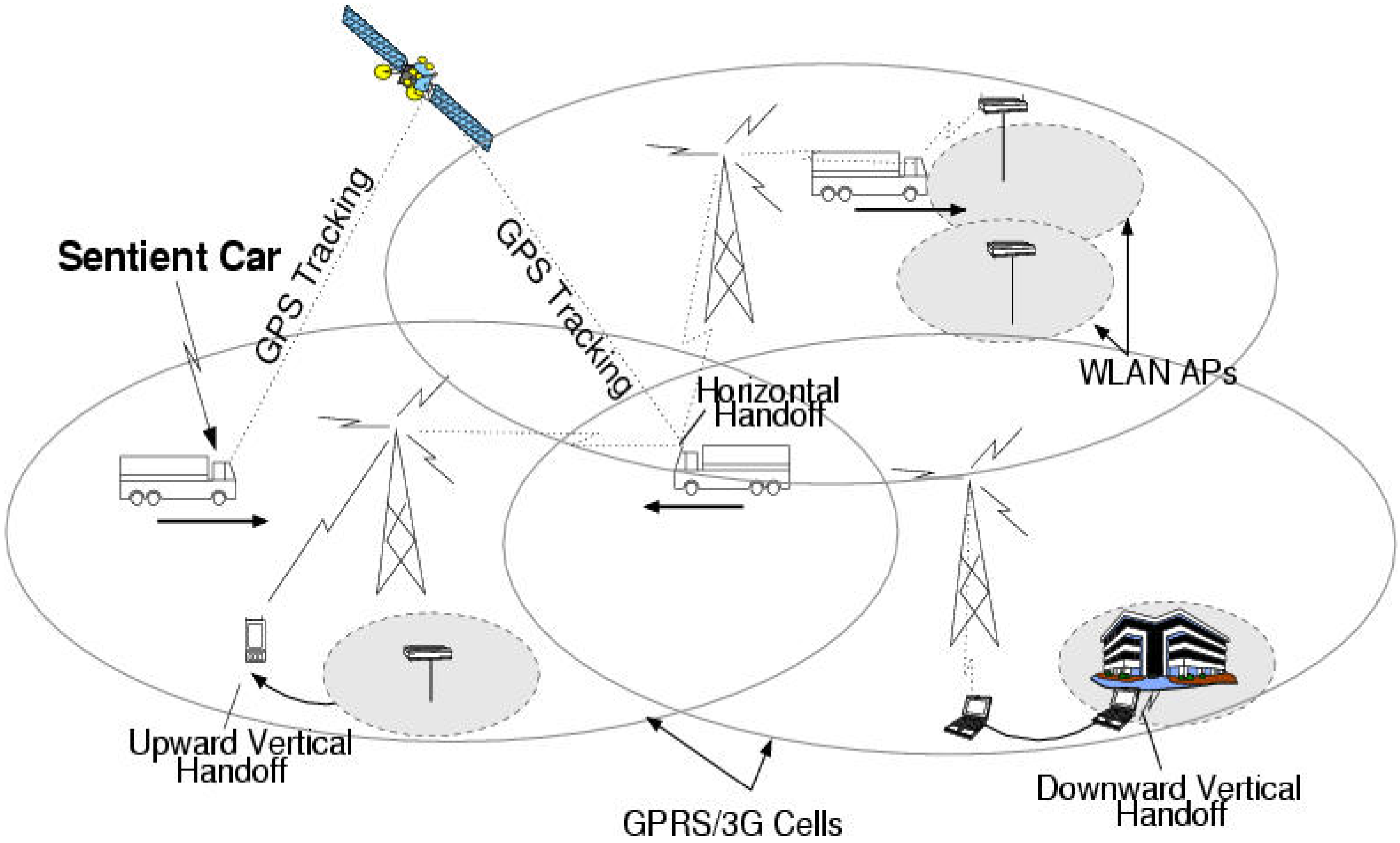
Evolution.
Networks.



Mobility.
Protocols.



Mobility.
Scenario for Next Generation Networks/4G.



P. Vidales, C. J. Bernardos, G. Mapp, F. Stajano, J. Crowcroft, A Practical Approach for 4G systems: Deployment of Overlay Networks, IEEE TRIDENTCOM, February 2005.

P. Vidales, C. J. Bernardos, I. Soto, D. Cottingham, J. Baliosian and J. Crowcroft, MIPv6 Experimental Evaluation using Overlay Networks . Computer Networks, Vol 10/11, July 2007 (ISSN 1389-1286)

NGN aka 4G.
Definition.

Fourth Generation (4G) is an approach to integrate various existing technologies into a unified ubiquitous platform. Opposite to its predecessors, the also-called Next Generation Networks (NGN) are not directly related to the design and deployment of a new and better wireless technology, but with the better used of current ones. This convergence process poses many challenges, and the urgent need for solutions on these lines.

"Interoperation is more than merely passing waveforms and bits successfully; interoperation among the supporting services for communications, such as security and access priority, is highly complex when heterogeneous networks interconnect".

Computing and Communications in the Extreme (1996)

Motivation.
Why 4G systems?

- The perfect network will not exist. Due to physical constraints, the perfect network with unlimited bandwidth and ubiquitous coverage will not become reality soon.

- This paradigm copes with the proliferation of WLANs, ad hoc, P2P, and other networking paradigms (NEMO), technologies, and services.
  - Social Networks (ad hoc, P2P)
  - NFC (RFID based systems)
  - Mobile Internet/services

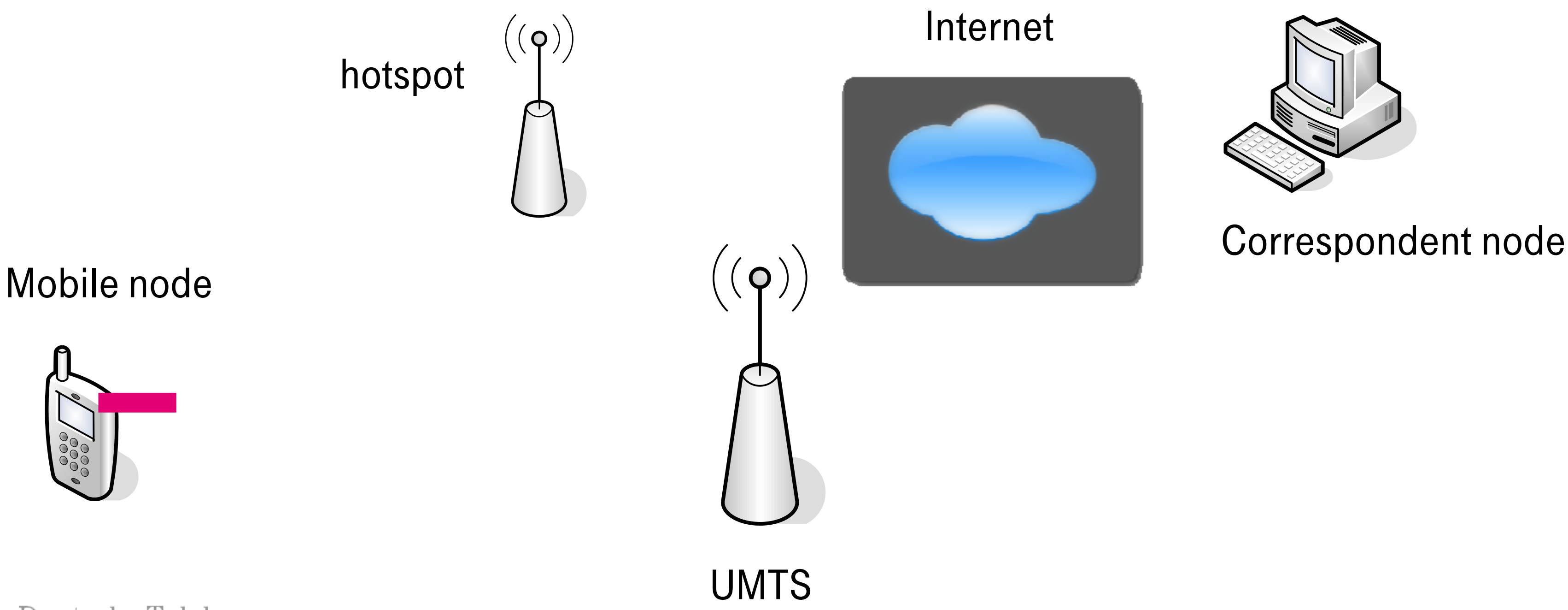
- Two is always better than one. The integration of technologies will always be better, if the correct integration strategy is followed; even the best of all benefits from the cooperation with others.

4G systems.
Characteristics.

- Multi-homed mobile devices.
- Multiple access technologies.
- Unified access platform to an Extended-Backbone (X-bone) formed by independent wired-wireless and fixed-mobile technologies.
- Services exploiting the new advantages (always-on access, heterogeneity, diversity, simultaneous access to different networks).
- Autonomic Communication system sharing complexities and embedding certain management functionalities within the system itself.
- Highly complex dynamics and interactions.

The goal.
Seamless mobility.

Transparent migration of ongoing data flows between two access points belonging to independent heterogeneous technologies is achievable, and tools and mechanisms for supporting this type of mobility should be placed within the next generation networking architectures.



Mobility.
Basic definitions.

Mobility Management is one of the major functions of a GSM or a UMTS network that allows mobile phones to work. The aim of mobility management is to track where the subscribers are, so that calls, SMS and other mobile phone services can be delivered to them.

Mobile IP (or MobileIP) is an Internet Engineering Task Force (IETF) standard communications protocol that is designed to allow mobile device users to move from one network to another while maintaining a permanent IP address. Mobile IPv4 is described in IETF RFC 3344 and updates are added in IETF RFC 4721. Mobile IPv6 is described in IETF RFC 3775.

The **Session Initiation Protocol (SIP)** is an application-layer control (signaling) protocol for creating, modifying, and terminating sessions with one or more participants. It can be used to create two-party, multiparty, or multicast sessions that include Internet telephone calls, multimedia distribution, and multimedia conferences. (cit. RFC 3261). SIP is designed to be independent of the underlying transport layer; it can run on TCP, UDP, or SCTP

Wikipedia.com

Mobility.
More definitions.

The **Host Identity Protocol (HIP)** provides a method of separating the end-point identifier and locator roles of IP addresses. It introduces a new Host Identity (HI) name space, based on public keys. The public keys are typically, but not necessarily, self-generated.

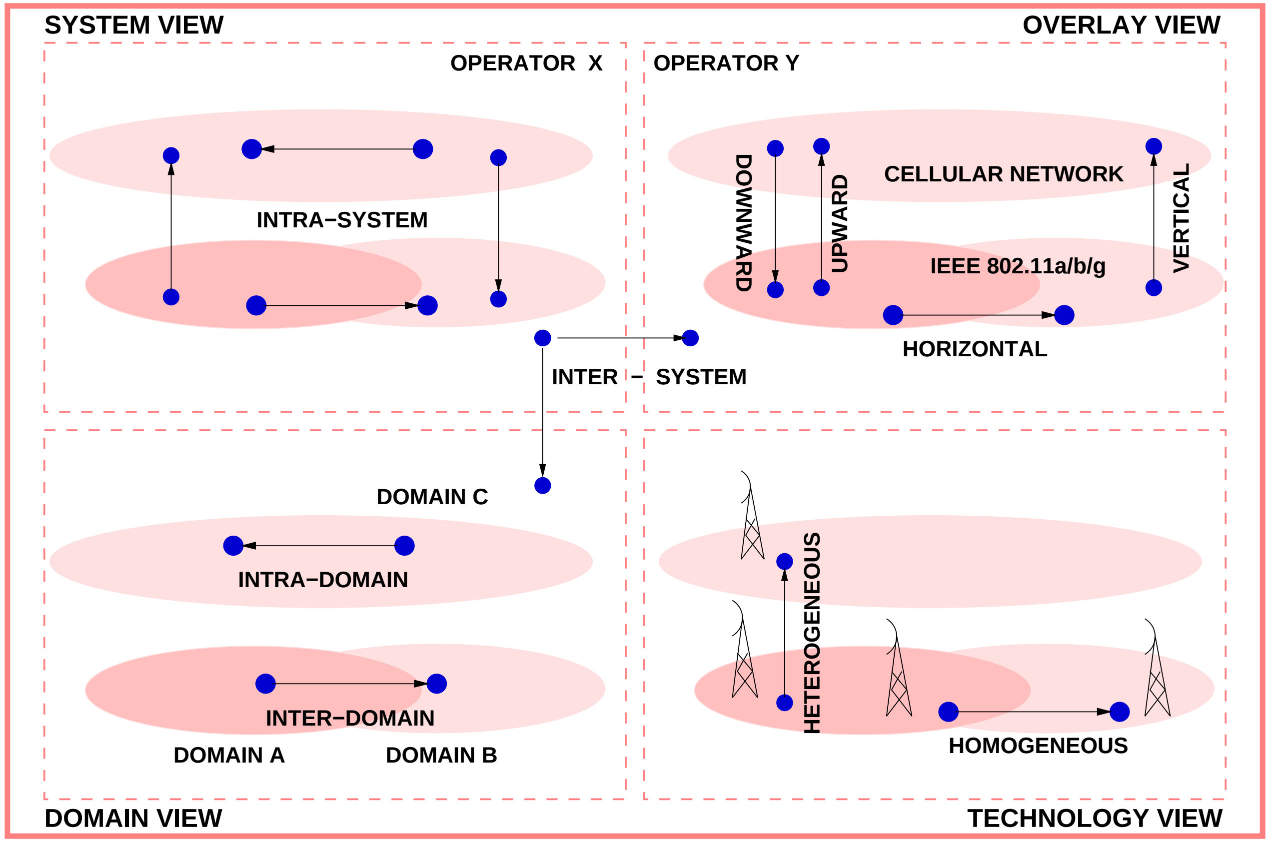
In cellular telecommunications, the term **handoff (handover)** refers to the process of transferring an ongoing call or data session from one channel connected to the core network to another.

Vertical handoff refers to a network node changing the type of connectivity it uses to access a supporting infrastructure, usually to support node mobility.

Roaming is a general term in wireless telecommunications that refers to the extending of connectivity service in a location that is different from the home location where the service was registered

Wikipedia.com

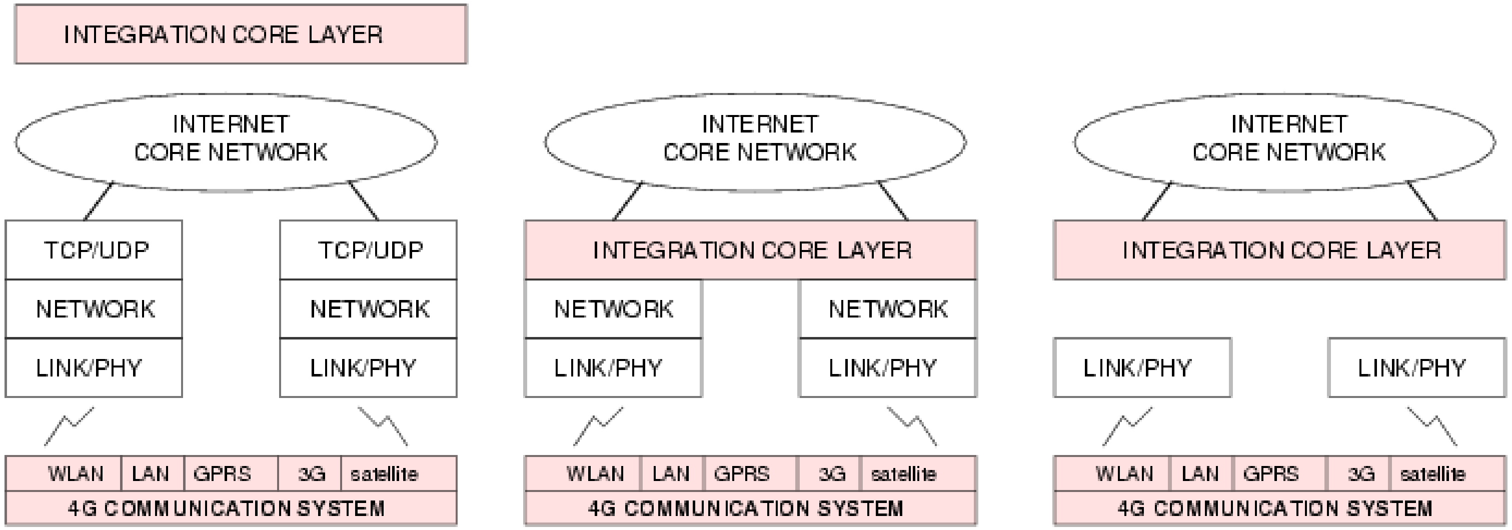
Handover.
Taxonomy.



Mobility management.
Implementation at different level.

Things to consider:

- Performance versus modifications.
- Functionality duplication vs. level of integration.

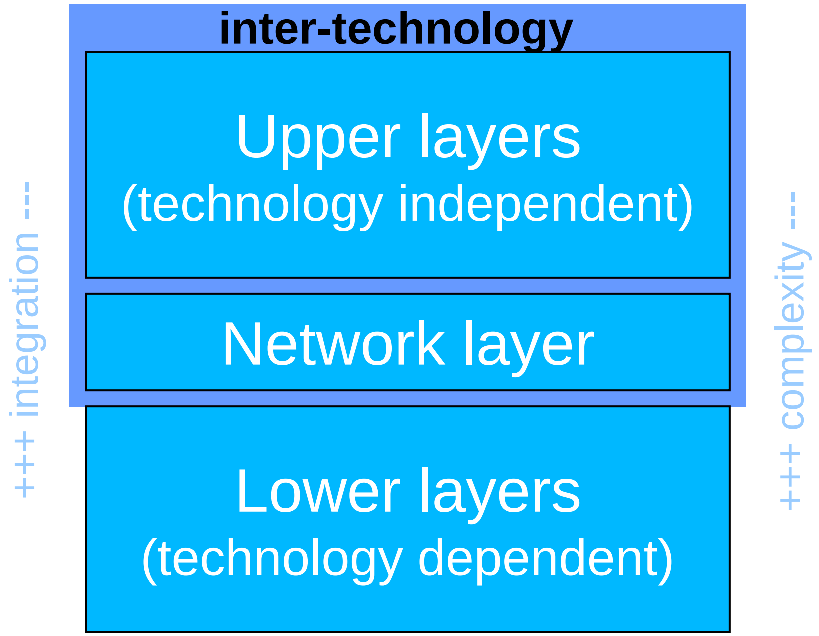


A. Tunneled Networks Model **B. Hybrid Networks Model** **C. Heterogeneous Networks Model**

Mobility management.
Implementation at different layers.

Things to consider:

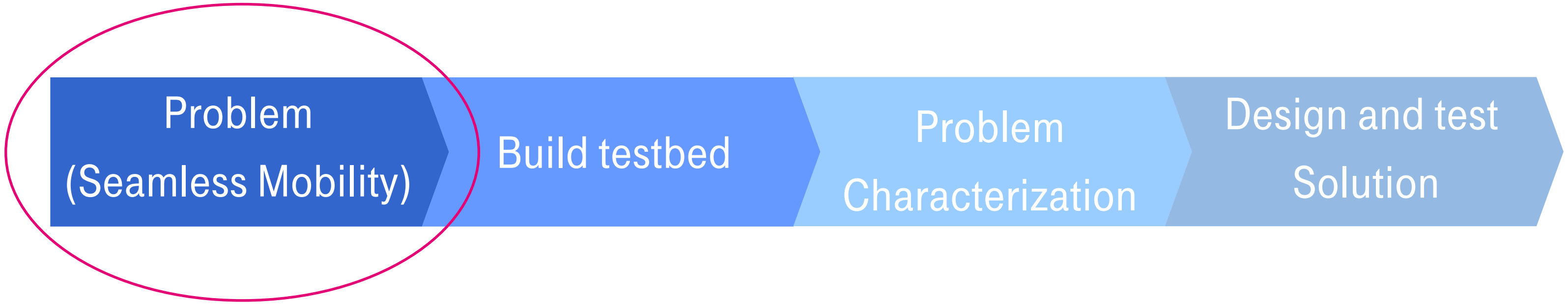
- Inter-layer independence versus overhead.
- Complexity versus performance.
- Protocol modification versus functionality.



Enabling Mobility.

Mobility management solutions.

Method.
From problems to solutions.



Mobile IPv6.
IETF improvements.

HMIPV6

- Reduce handover signalling.
- Organise network into a hierarchical model independent from network domains.
- Exploit local mobility more efficiently.

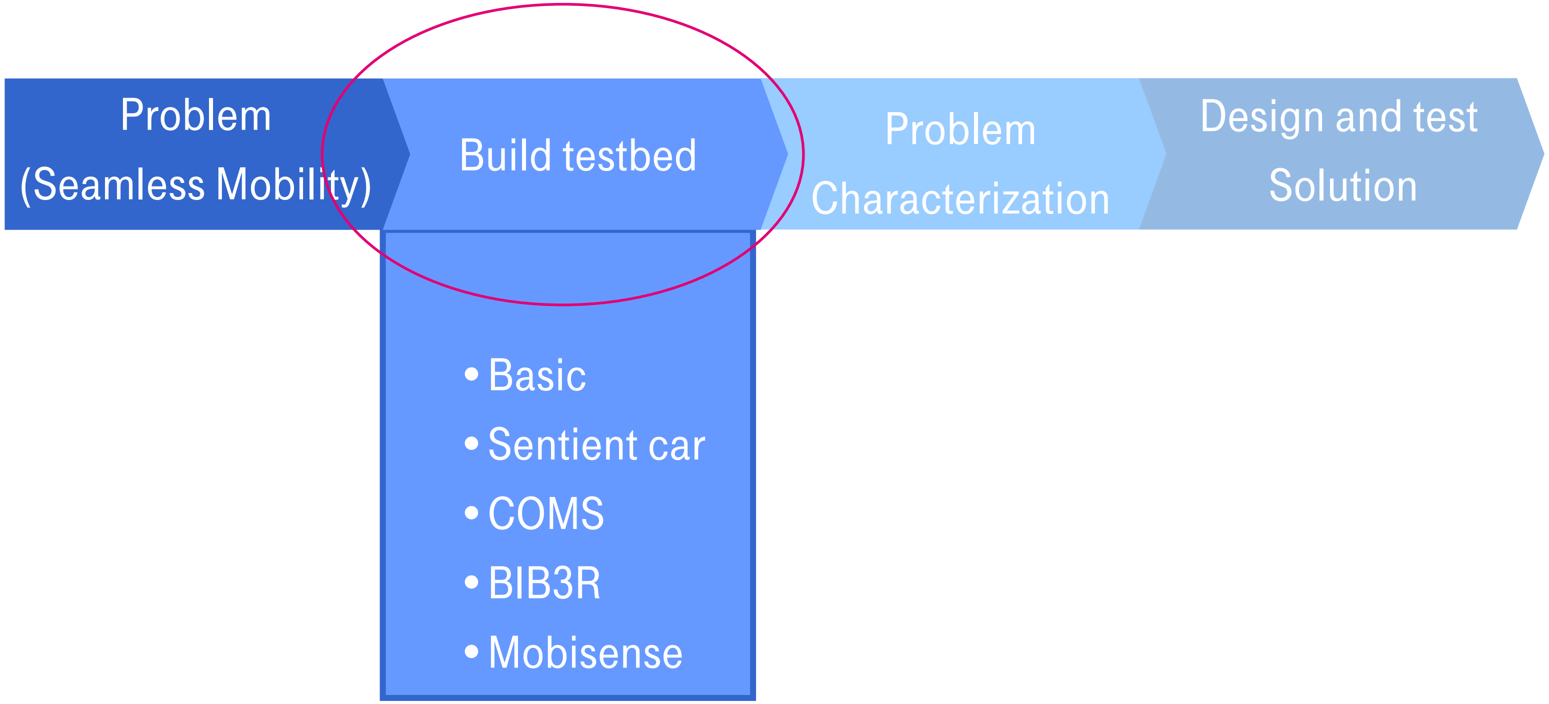
Fast handovers

- Anticipate movement based on layer-two triggers (signal strength).
- Performs well in intra-domain handovers.

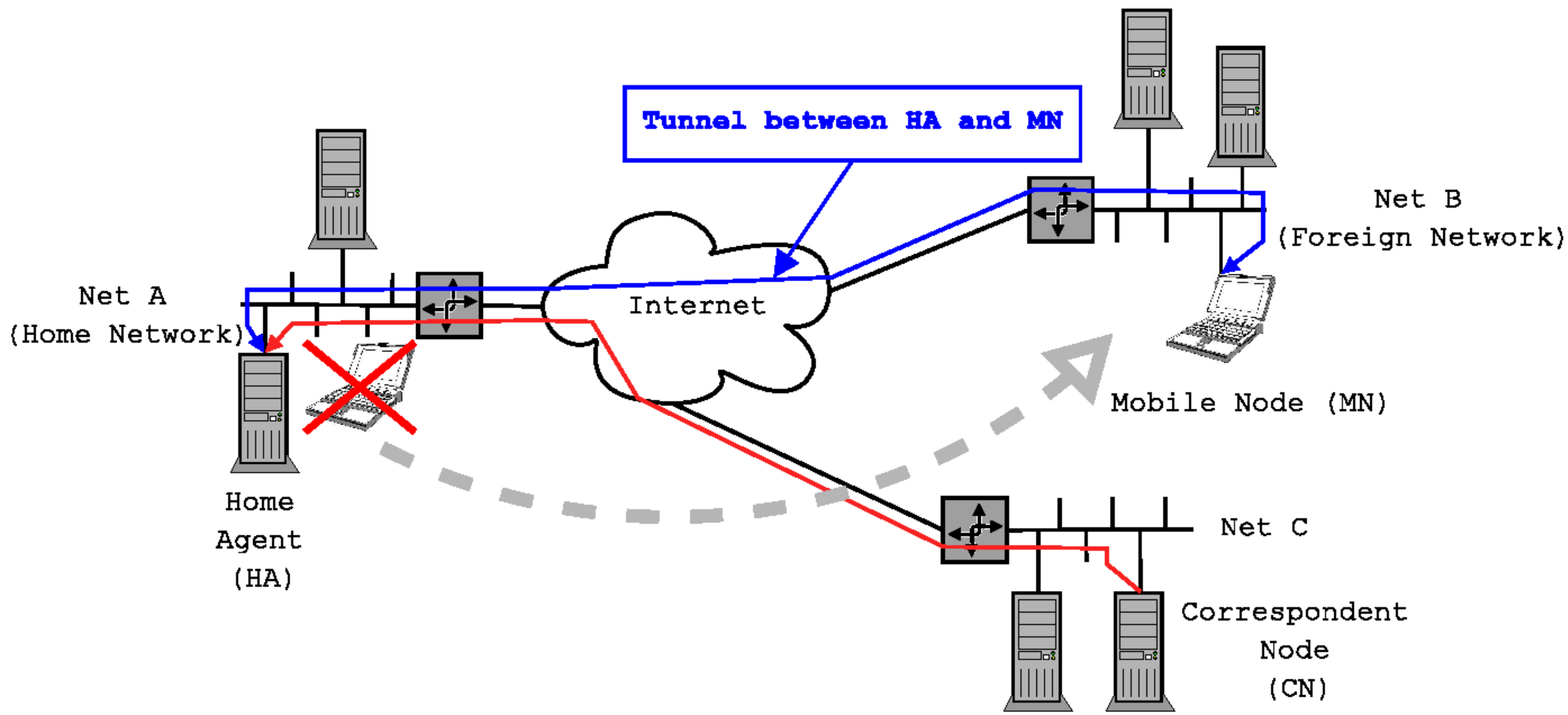
Mobile IPv6.
So, why to improve Mobile IPv6 for vertical handovers?

- IETF optimizations do not consider 4G systems inter-technology handovers (disparity in L2 characteristics).
- These methods were designed to reduce horizontal handover latency.
- HMIPv6 and FMIPv6 are not equally efficient for vertical (inter-domain, inter-technology) handovers.
- IETF workgroups mentioned do not discuss or exploit the 4G scenario.

Method.
From problems to solutions.



Testbed 1.
Basic mobility testbed.

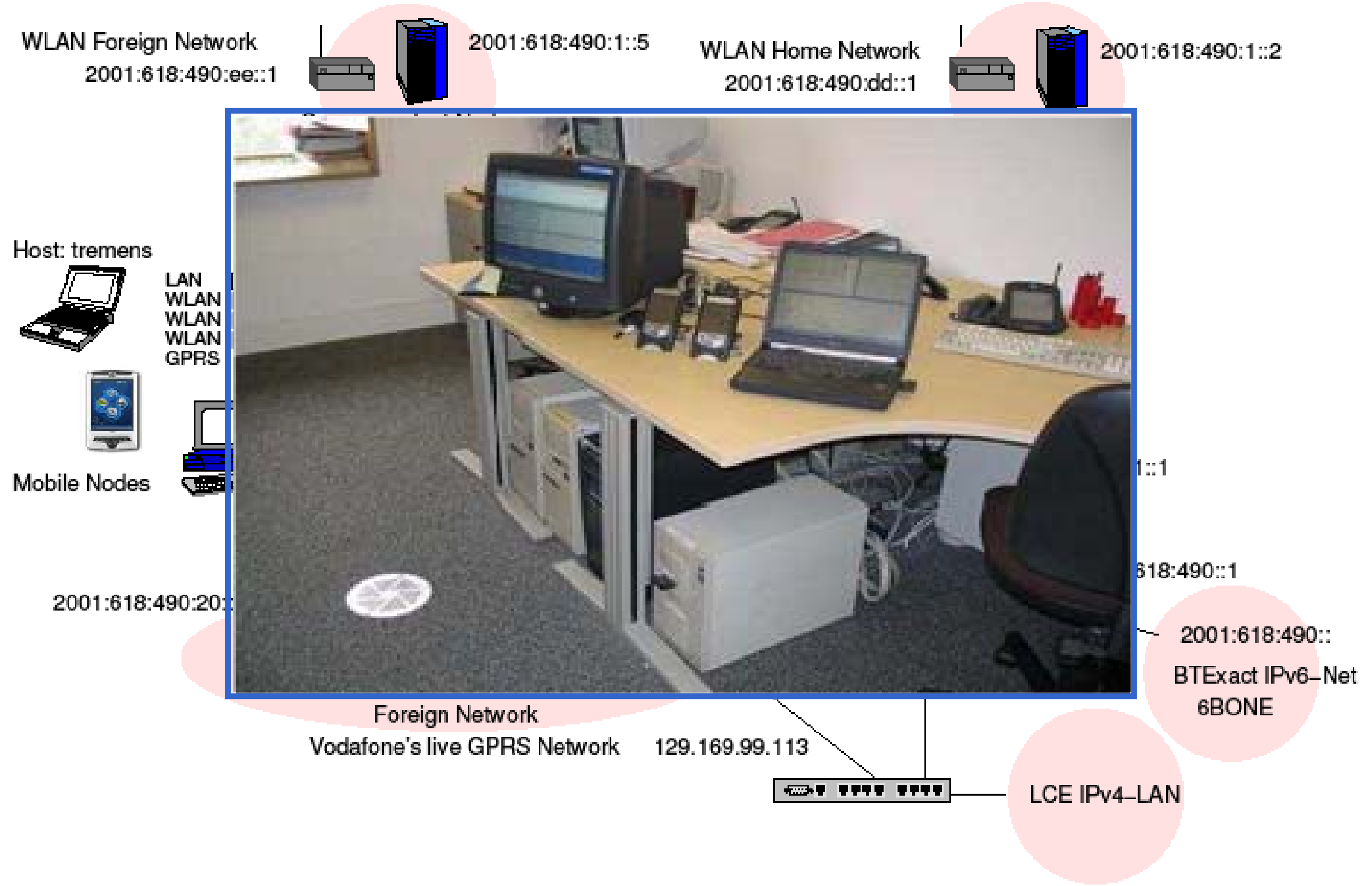


The basic components are mobile node and correspondent node, depending on the mobility management solution you may have one or more network (home) agents.

Testbed 2.
The Sentient Car project.

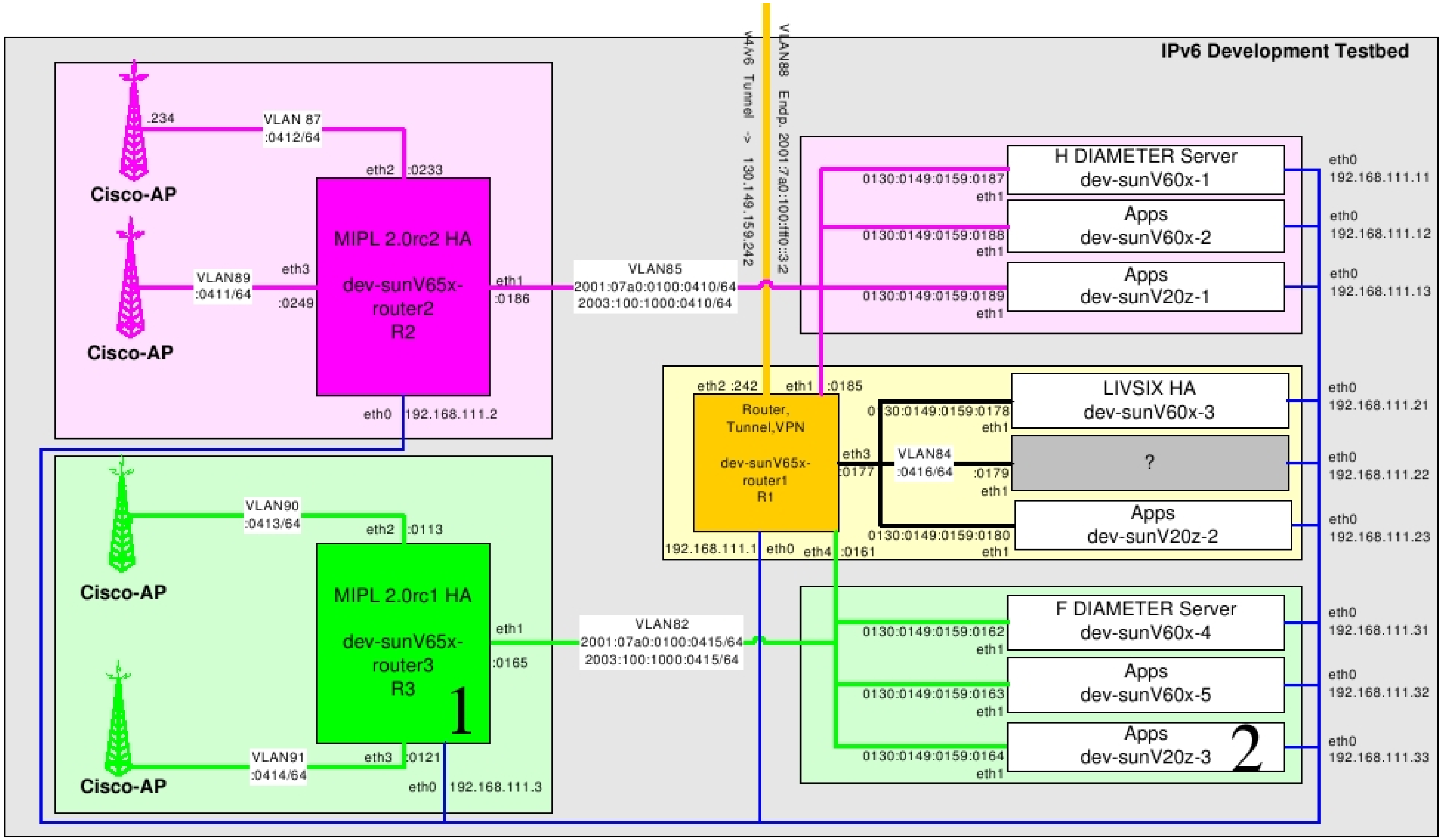
Mobile testbed, deployed in a van, performed studies on high mobility scenarios, using MIPv6 as the underlying mobility protocol [IEE LBS 2002].

Testbed 3.
The COMS project.



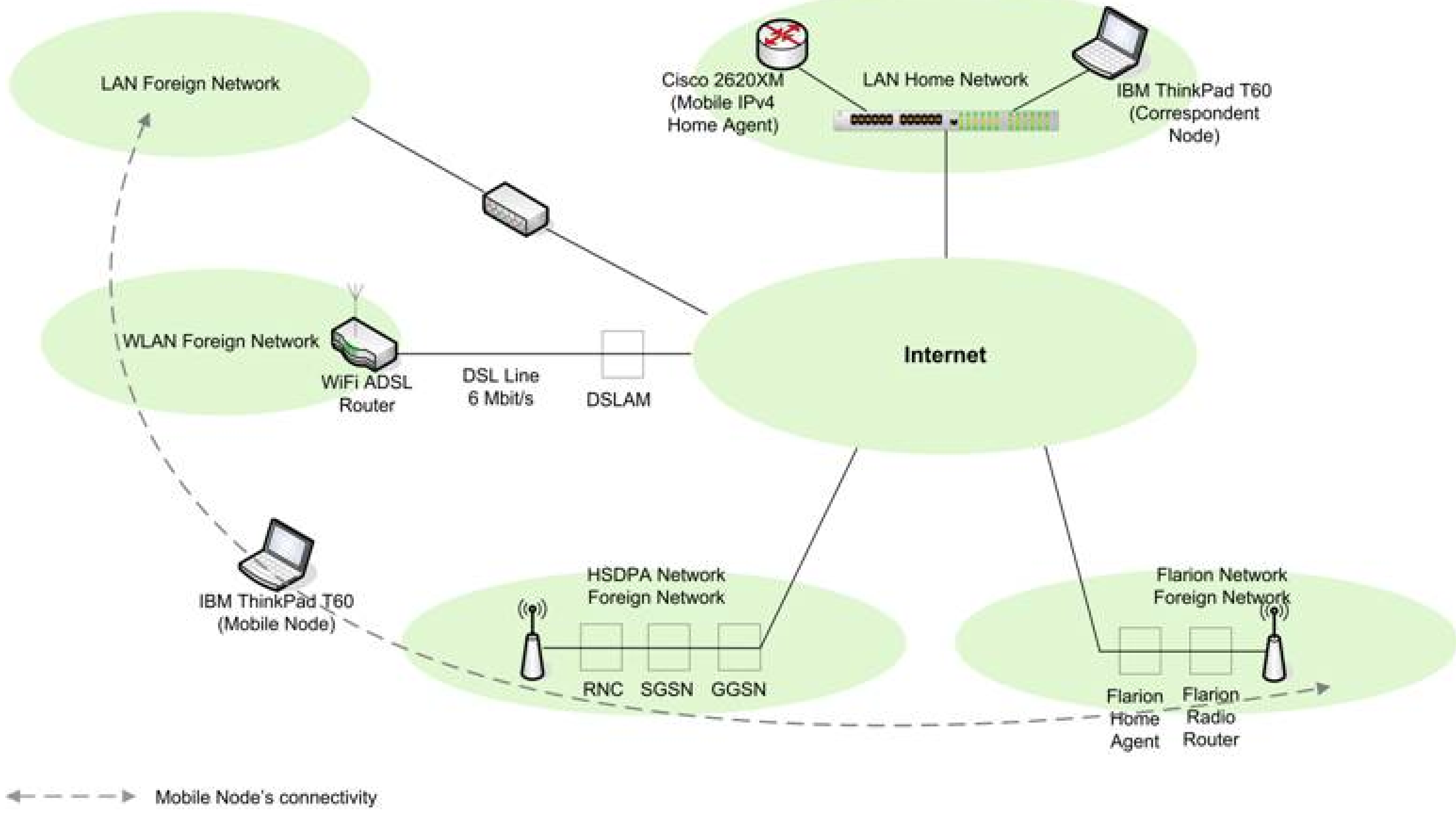
Testbed integrated with operational Vodafone GRPS network, performed studies on mobility with real traffic conditions [Tridentcom 2005].

Testbed 4.
The BIB3R project.



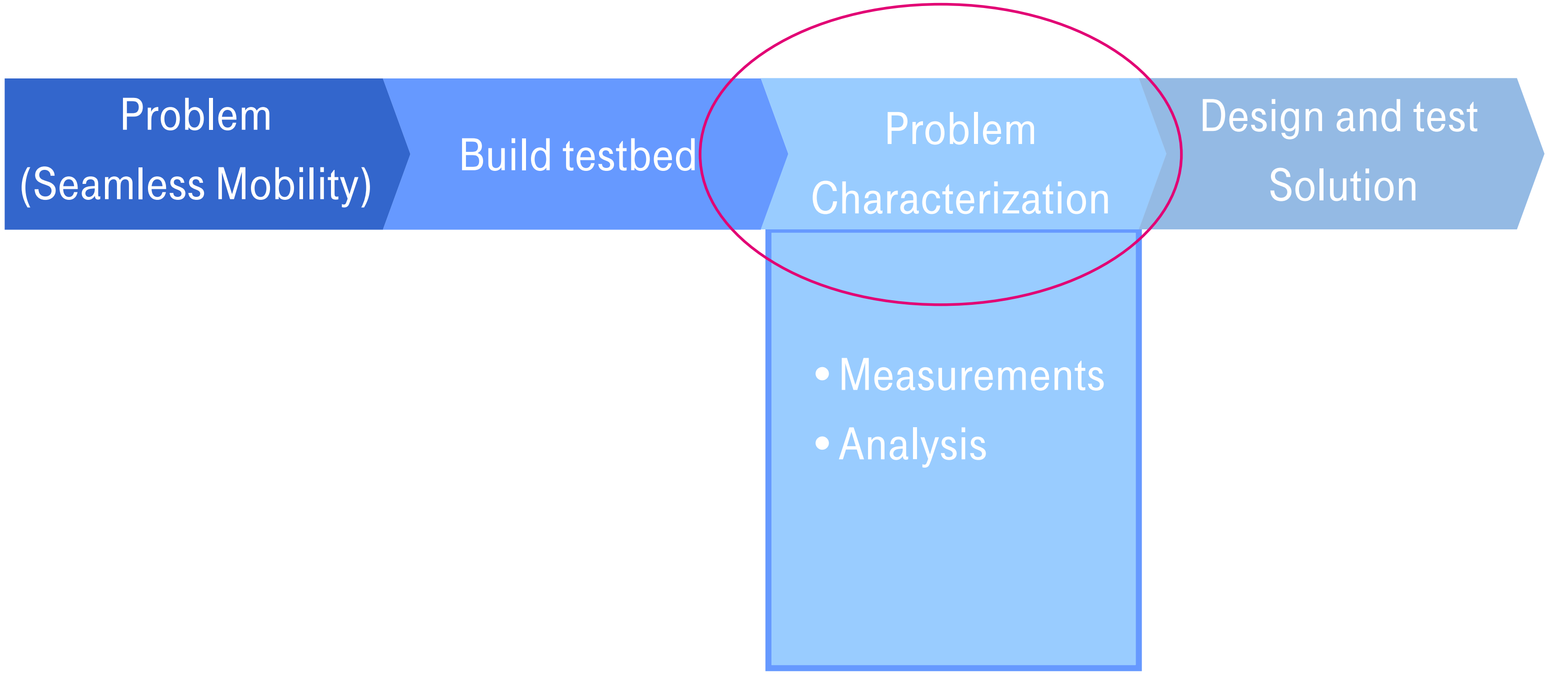
Full-flesh testbed including MIPv4/v6, AAA protocols, study of mobility in heterogeneous environments [Tridentcom 2006].

Testbed 5.
The Mobisense project.



Pre-release Flarion technology, MIPv4 mobility management, SIP for session layer protocol, study of user perceived mobility [Tridentcom 2008].

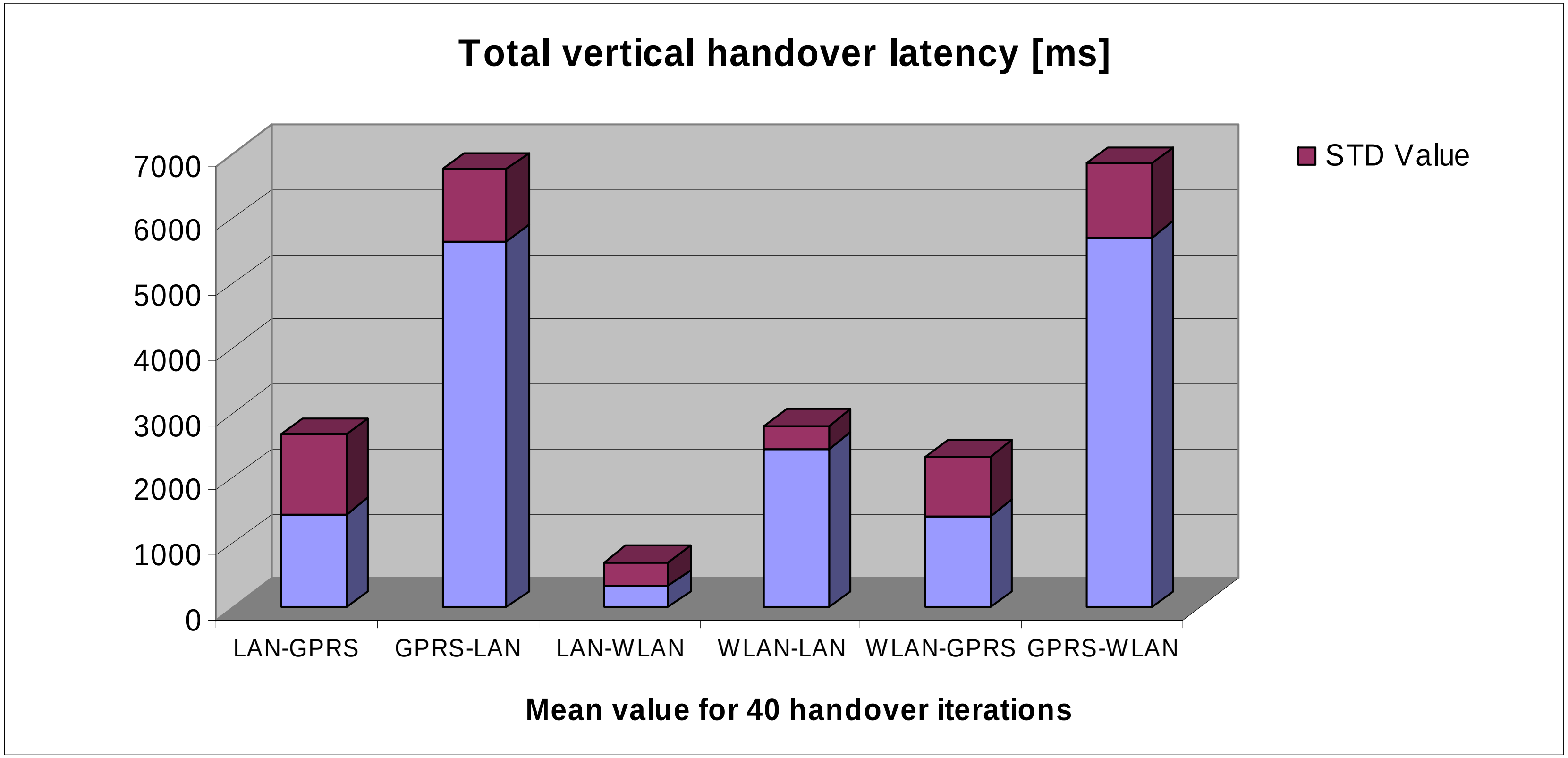
Method.
From problems to solutions.



VH latency measurements.
Characterization of the latency at different layers.

- Measure the impact of mobility on TCP/IP stack using MIPv6 as the management protocol.
- Latency at the network layer.
- Latency at the transport layer (UDP/TCP).
- Theoretical Protocol overhead.
- Latency characterisation.
- Determination of adaptation component.
- We concluded that MIPv6 needs to be optimised to supuport seamless networking in 4G systems (vertical handovers).

VH measurements.
Latency at the network layer (IP).



VH characterization.
MIPv6 latency characterisation.

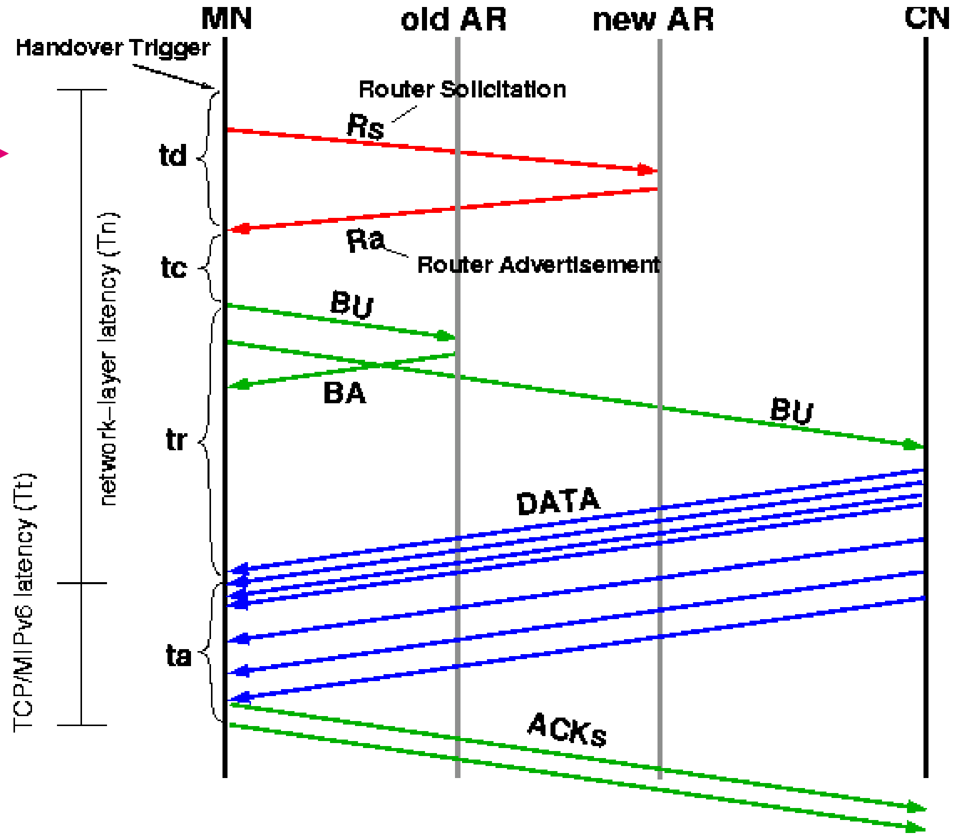
- Latency at the Transport Layer using TCP.
- Latency at the Transport Layer using UDP is equivalent to the latency at the Network Layer.
- Partition of vertical handover latency:

$$Tt = td + tc + tr + ta$$

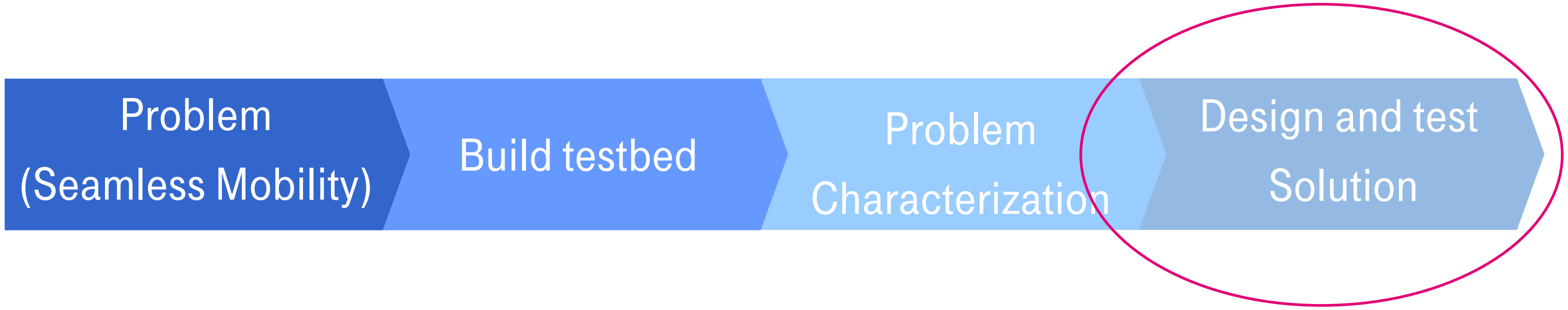
	WLAN->GPRS				GPRS->WLAN			
[ms]	MIN	MAX	MEAN	STD DEV	MIN	MAX	MEAN	STD DEV
td	200	1148	800	304	739	2241	3803	919
tc	0.853	0.890	0.870	0.01	0.380	1.062	1.186	0.233
tr	2339	3649	2997	395	2585	4654	7639	1611
Tt	3323	4438	3806	310	5322	8833	6896	1118

VH characterization.
MIPv6 latency improvements.

- RA frequency
- RA caching
- BU simulcasting
- Soft-handover



Method.
From problems to solutions.



Solution.
MIPv6 protocol improvements.

RA frequency

- Discovery time is reduced, but there is a limit for each technology

RA Caching

- Discovery time reduced to zero, but needs ubiquitous upper layer

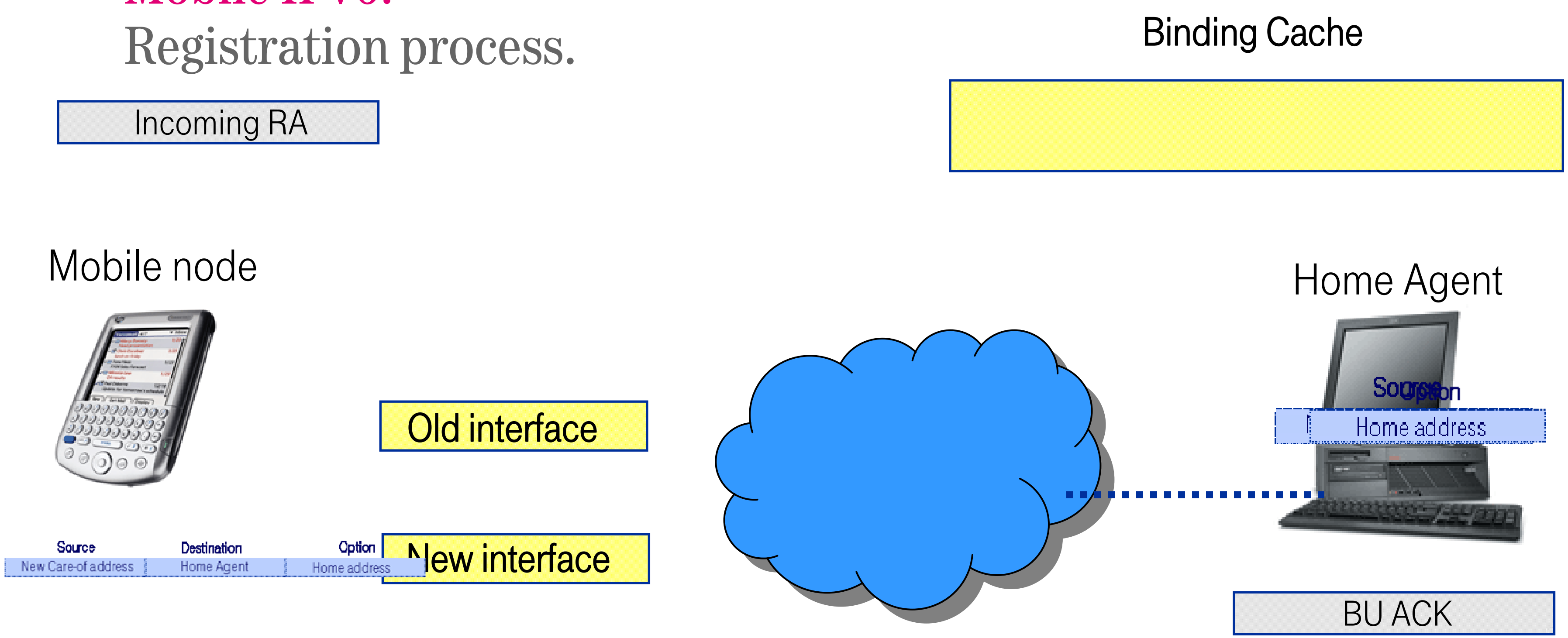
BU simulcasting

- Registration time reduced to 1.5 * RTT of fastest network, but requires anticipation

Soft handover

- Packet losses reduced to ~ zero, but needs overlapping networks
- It is the best option for Overlay Networks, but there are some details to be solved

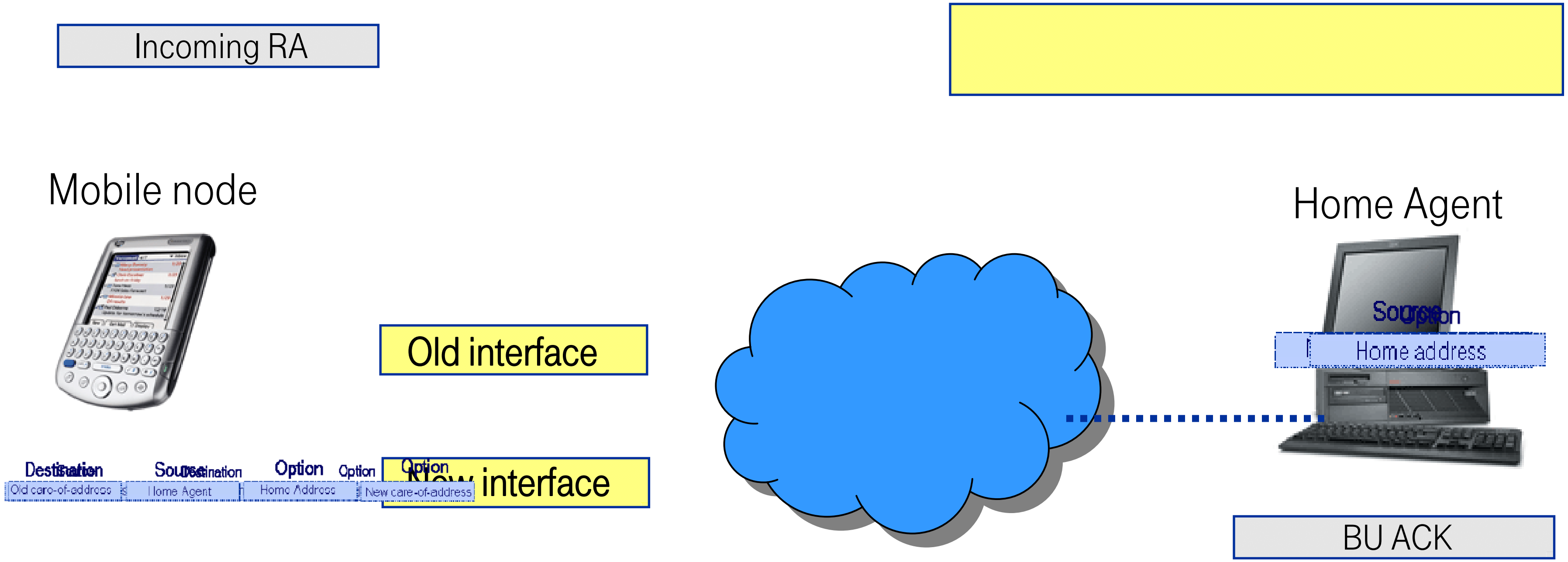
Mobile IPv6.
Registration process.



- The registration time is equivalent to: T_RR + T_BU = 1.5 RTT + 1 RTT
- In homogeneous environments where RTTs are similar in every access route, the registration time is more or less constant
- In 4G systems, where handover is performed between to disparate wireless technologies, the registration time varies according to the RTT of the NEW network – which can be really high, for example, RTT in GPRS networks

Solution.
BU simulcasting.

Binding Cache



Destination	Source	Option	Option
Old care-of-address	Home Agent	Home Address	New care-of-address

- Overhead: One additional option (alternative care-of address)
- Reduces registration time to 2.5 of the fastest interface
- Dual-processing of BU, but only one persist during new connection

Analysis.
BU simulcasting.

Upward handover	without BU simulcasting	with BU simulcasting	Reduction
LAN→WLAN	7.5 ms	1.9 ms	75%
WLAN→3G	750 ms	156 ms	79.2%
3G→GPRS	2500 ms	1000 ms	60%
WLAN→GPRS	2500 ms	506 ms	79.76%

Conclusions.
The suite of solutions help reducing MIPv6 VH latency.

- IETF not very into HETEROGENEOUS roaming.
- IETF does not specified handover-related issues, just HoA and CoA management.
- IETF standards cover the general scenario conditions.
- Other projects not specialise in exploiting overlay model.
- Need for new solutions.

Mobility.
User perception.

Everything you see or hear or experience in any way at all is specific to you...

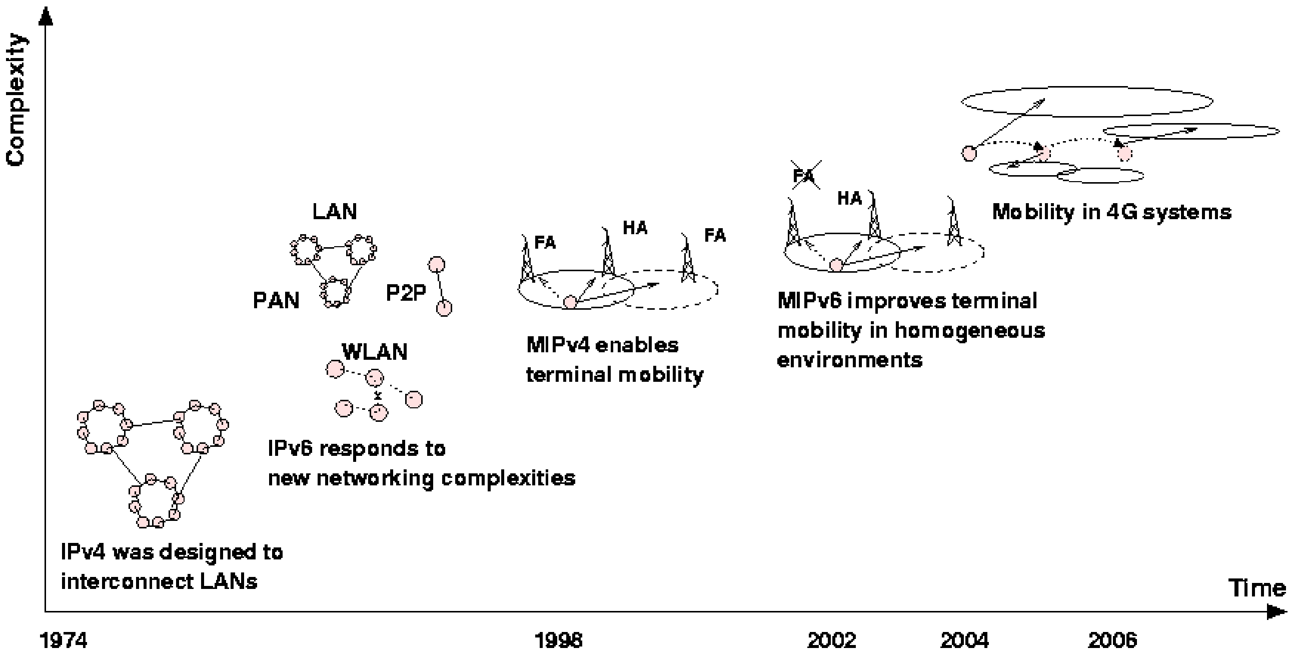
Douglas Adams, “Mostly Harmless”

Agenda.

- Motivation
- Current approaches for voice quality assessment
- Mobisense testbed
- Results
- Future work and Conclusions

Mobility.
A new perspectives of service distribution in NGNs.

- Networks will converge in an ALL-IP platform.
- Mobile communication systems will bring together heterogeneous access technologies (Wi-Fi, UMTS/HSDPA, Flarion, etc.)
- This convergence will demand seamless mobility across independent systems.
- The trade-off between network coverage and link quality become a new challenge to satisfy the mobile user.



Our objective.
User perception of network phenomena.

Trace analysis and quality perception happens in two different areas: **networking** and **usability.** Our motivation is to bring these areas together to gain inside on the perception of network phenomena unknown to the community.

Networking QoS vs. User perceived performance.
Should or can these be merged?

Networking QoS

- Dropped packets
- Delay
- Jitter
- Reordering
- Errors

User perceived performance

- Happy customer
- Degree of satisfaction
- Mean Opinion Score (MOS)
- Quality of Experience (QoE)

Network traces analysis

Human subjective test

Perception models for new network phenomena

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Current approaches of voice quality assessment (1/2).
Measuring perception.

Auditory methods

- Listening or conversational test.
- Utilitarian (single feature) or Analytic (subset of features).
- Most common scale MOS (or 5-point ACR scale).
- Other scales: 11-point ACR, 7-point ACR (for German and French).

Instrumental methods

- Comparison between base signal and test signal (PSQM, TOSQA, etc.)
- To reduce the necessity of time-consuming and costly perception tests.
- Difficult to express speech quality using basic signal measures like SNR.

Current approaches of voice quality assessment (2/2).
Considering network characteristics.

Parameter-based models

- Estimate quality from instrumentally measurable characteristics of the network.
- These models try merge network QoS and user perceived quality.
- Useful for network design and planning (supported by Telecom operators).
  - SUBMOD (British Telecom).
- E-model (2005) – Empirical model based on auditory tests (listening and conversational).
  - Includes impairments due to echo and transmission delay.
  - Transmission Rating Scale (E-model) can be mapped to MOS.
  - Many extensions have been done to the E-model.

The E-model.
Parametric method of voice quality assessment.

- The E-model (ITU-T G.107) is a recommendation of the ITU-T model for network planning.
- It uses measurable parameters (e.g. delay, packet loss) to predict transmission quality.
- The E-model uses the assumption that psychological quality impairment factors have additive character.
- The basic ITU-T G.107 support only narrowband voice quality, however. wideband extension (ITU-T G.107 Amendment 1) is already part of the recommendation.

$$R = R_0 - I_s - I_d - I_{e-eff} + A$$

Default SNR

Impairment factors appearing simultaneous to the transmission.

Impairment factors caused by transmission delays.

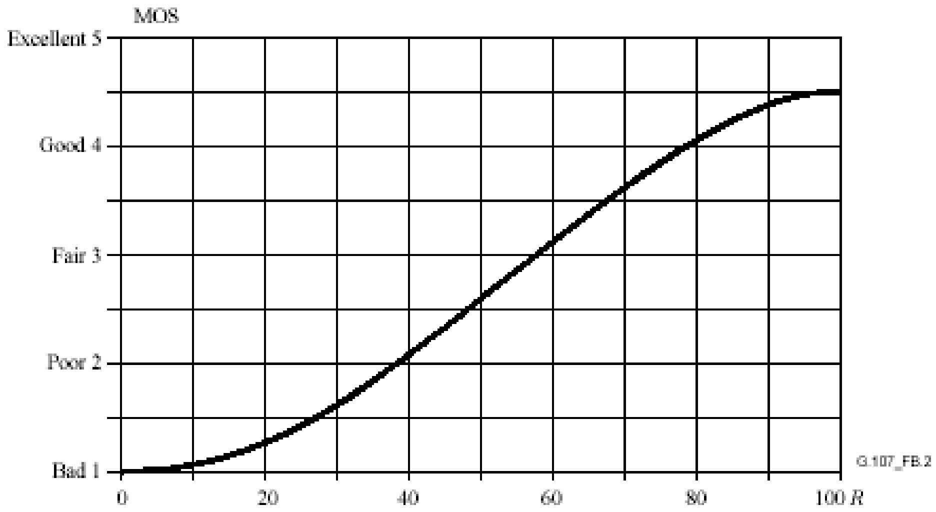
Effective equipment impairment factor.

Advantage factor.

R-factor to MOS mapping
User-centric voice quality estimation.

- The computed R factor can be converted to the MOS (Mean Opinion Score) both describe user perception.

Quality of the speech	*Score*
Excellent	5
Good	4
Fair	3
Poor	2
Bad	1



Source: ITU-TG.107

VoIP quality assessment.
Related projects.

- BIB3R testbed used for emulation of NGN **[Steuer et al., Tridentcom06]**.
- Study of network handover performance **[Vidales et al., JSAC 2006].**
- Using of the E-Model to take routing decisions [**Rajendran, NEC Technical report].**
- Quantifying of Skype user satisfaction **[Chen et al, ACM Sigcomm 06].**

Mobisense project:

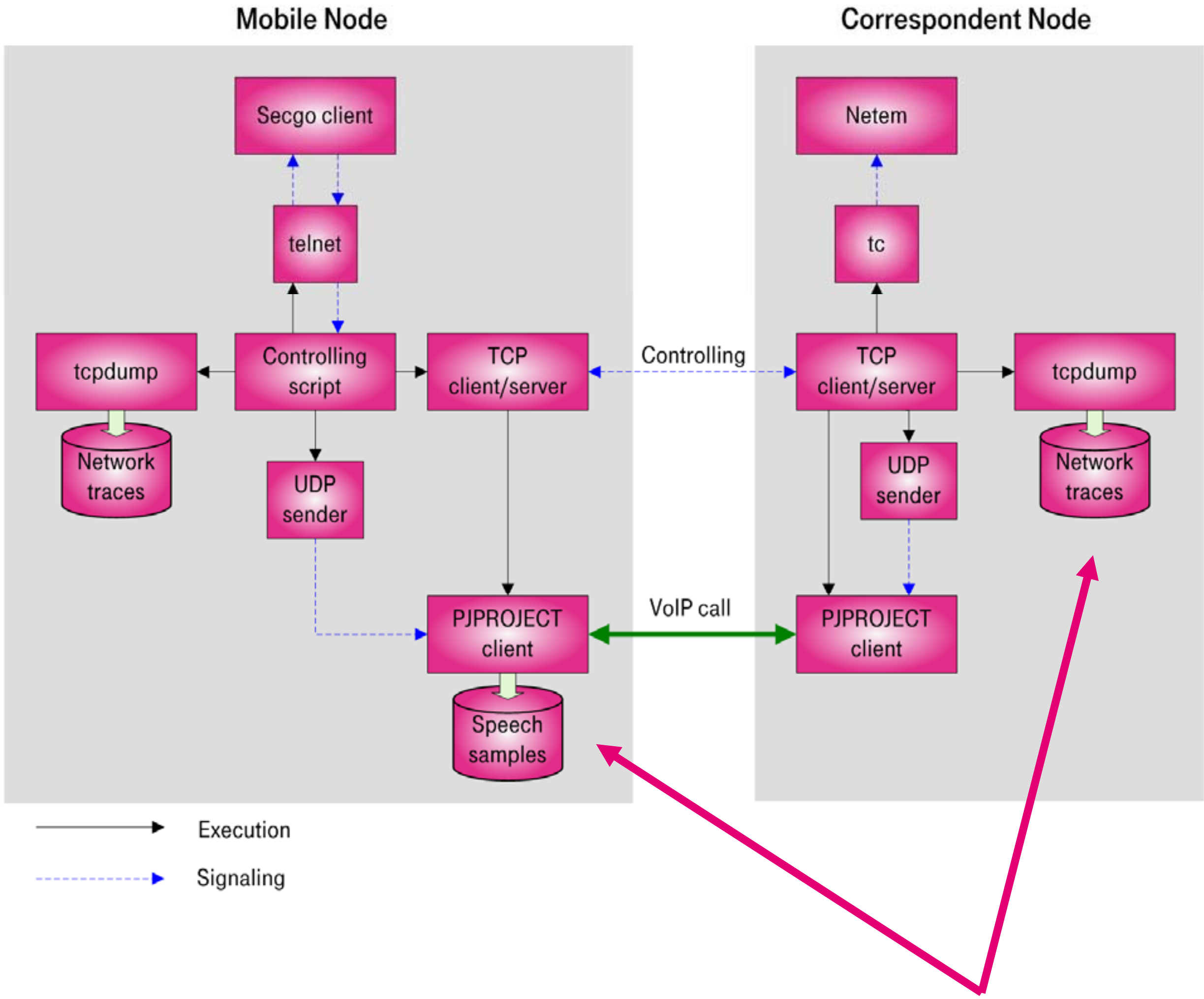
A thorough assessment of real user perception of mobility in NGN has not been done.

Sample application: Voice over IP.

Agenda.

- Motivation
- Current approaches for voice quality assessment
- **Mobisense testbed**
- Results
- Future work and Conclusions

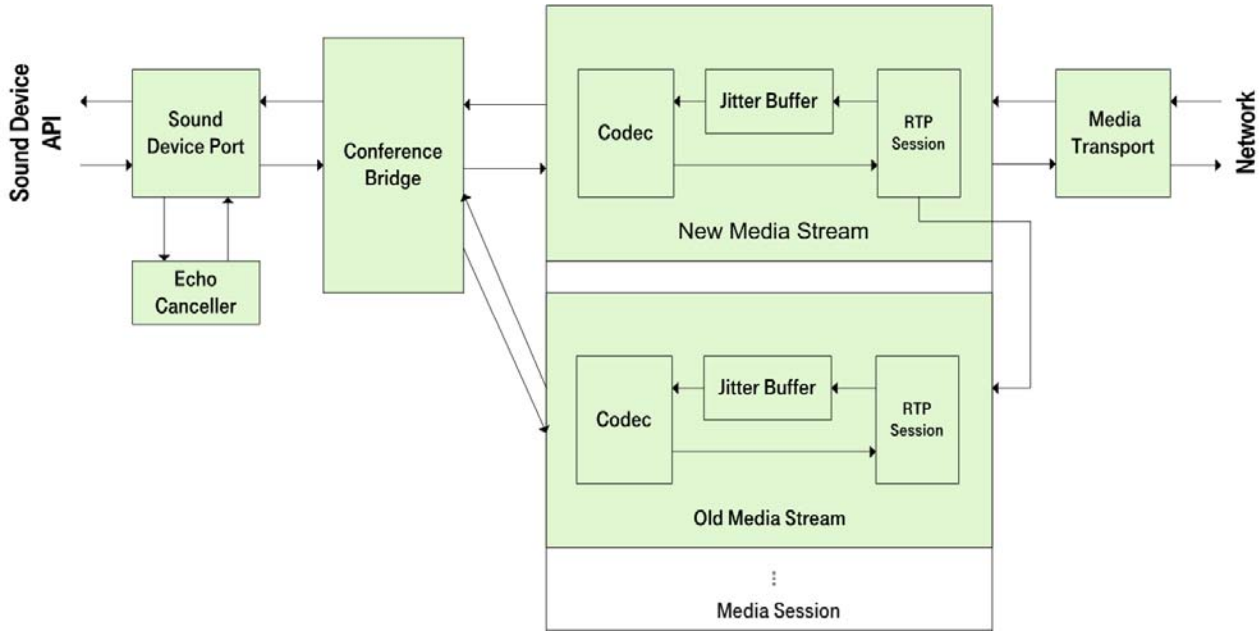
Mobisense testbed (2/2).
Collection happens in both: application and network layer.



Wideband and narrowband quality transitions.

Seamless codec changeover during VoIP calls.

- A codec changeover solution has been designed and implemented to provide seamless codec changeover during VoIP calls.
- The solution uses two parallel audio streams and RTP filtering during the codec changeover phase.
- The solution reduces the application-layer disruption on the audio streams.



Mobisense testbed functionality.
The setup enables us to evaluate the effects of mobility.

There are multiple options of transmission control and monitoring:

- Access to different network technologies.
- Ability to change the network connection (network handover).
- Possibility to artificially change network conditions (packet loss, delay, etc.)
- Record network traces.
- Share available bandwidth using DSL and WLAN technologies.
- Perform VoIP calls over the networks.
- Support for different voice codecs (e.g. narrowband and wideband).
- Possibility to change voice codecs (codec changeover).
- Ability to record voice samples.
- Ability to record internal parameters of the VoIP application (e.g. jitter buffer monitoring).

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Merging user perception and network traces.
Our approach.

Networking

- Deep knowledge on NGN, specially mobility management, empirical work, and trace analysis.

<u>Objectives</u>

- Evaluate of mobility phenomena in NGN.
- Assess NGN VoIP services.
- Design mobility management solutions that consider the assess phenomena, and provide better QoE.

Usability

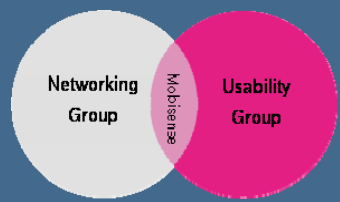
- Deep knowledge on quality models and extensive experience on subjective tests.

<u>Objectives</u>

- Evaluation and quantization of user perception of networking phenomena.
- Wideband-narrowband quality transitions.
- Extension of the existing perception models to include new phenomena.

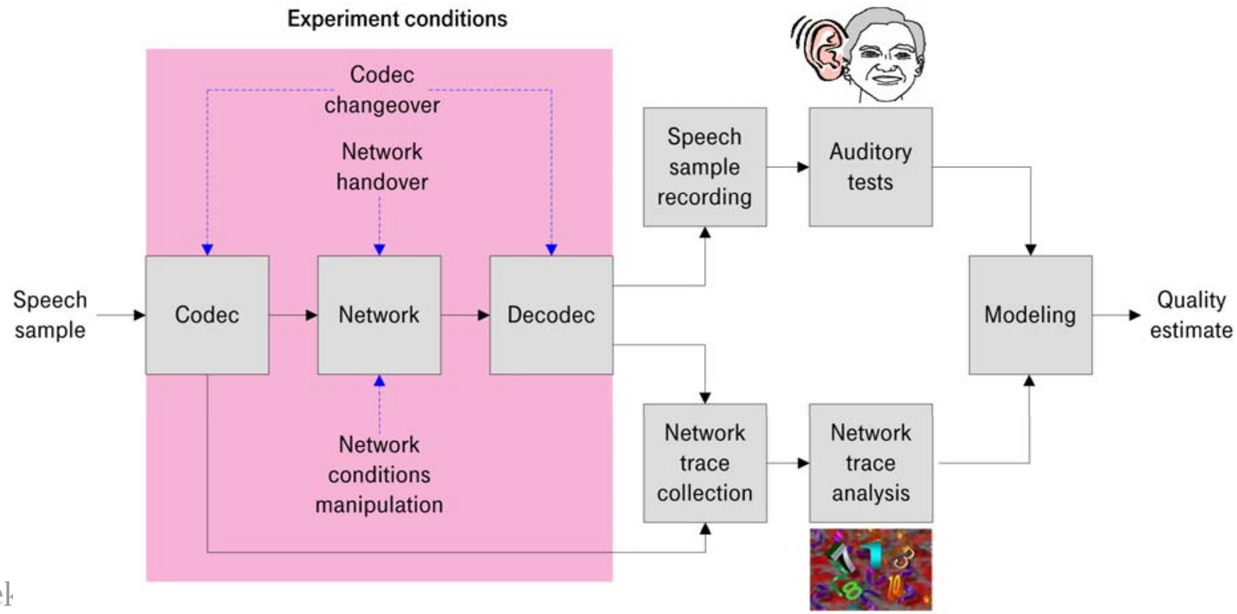
Our combines and exploits knowledge from both knowledge areas

Networking and usability.



Methodology.
Two-viewed evaluation of mobile VoIP service.

1. Speech samples are produced according to the conditions being investigated.
2. The quality of recorded samples is evaluated using auditory methods.
3. Network traces are collected during all the experiments.
4. A quality index is modeled, this correlated the investigated networking conditions to the user perceived quality.
5. Network traces are analyzed to correlated networking conditions to quality index.



User perception.
How users perceive this new phenomena?

How user perceive mobility in NGN?

- Are there any audible artifacts during network handover or speech codec switching ?
- What is the impact of the temporal position of a handover within a call (“recency effect”) ?
- How users perceive switch of coding technologies?
- What are the user expectations ?

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Conclusions.
We need some more answers to our questions.

- Correlation of networking and usability evaluation results.
- What assessed phenomena can be predicted with existing prediction models?
  - E-model (ITU-T Rec. G.107) or wideband E-model (under development)?
  - Reference-based signal model (ITU-T Rec. P.862, ITU-T Rec. P.862.2, P.OLQA)
  - Reference-free signal model (ITU-T Rec. P.563, WB extension) ?
  - Protocol-based model (ITU-T Rec. P.564, WB extension) ?
- Which of these models can be extended with the new networking phenomena of NGN?
- Do we need to develop a new model to predict mobility perception?
- How can we include user perception in mobility management solutions and service adaptation?

Future work.

- Prepare the testbed for online experiments.
- Extend experiments to include conversational subjective tests.
- Perform a thorough evaluation of the phenomena.
- Correlation of network traces analysis and results from subjective tests.
- Extend the phenomena to include Mobile TV (or video services in NGN).