Future Internet – A Mobile View

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I do not know what the Future Internet will be.

I assume that it is what will come after the Internet of today, though.

well, I do not know what the Internet of today really is, either….

Future Internet

- The debate started around six years ago, in the US.
- This was a revamp of the much older discussion on the next IP protocol.
  - IPv6 was (sort of) there already
  - IPv6 was not really taking up
  - Non-US countries were much more active than US
- The new discussion started on very different lines – a Clean Slate approach
  - "Post-IP" became a word

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Future Internet – the Clean Slate discussion

- "Given what we know today, if we were to start over with a Clean Slate, how would we design a global communications network?"
- "Ideally, how will the network look in 15-20 years, and how will we get there from here?"
- A **mobile** network trustable to be always there, always on, easy to use, universally accessible, secure, and economically viable ?

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Internet features and its relevance

- **Open standardized architecture**
  ➔interoperability and globalisation
  (early interconnection of all media, all networks, all countries)
  ➔innovation and economic growth
- **Separate** network, service and content **layers**
  ➔innovative and flexible business models
  (free access, advertising, community, flat fees, etc…)
  ➔innovation and economic growth
- **Distributed e2e architecture**
  ➔intelligence centered at the edges
  ➔ large number and types of contributors
  ➔peer-to-peer applications
  ➔innovation and economic growth

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Internet features and its relevance

- **Technology-neutral access**
  ➔ infrastructure competition
  ➔ explosion of broadband coverage
  (all types of new access, xDSL, cable, fiber, wireless)
  ➔ innovation and economic growth
- Remarkable demonstrated **resilience**
  ➔ global usage (regardless of efficiency)
  (lack of efficiency in wireless, optics, satellite…)
  ➔ economies of scale and economic growth

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Recall slide for engineers

The Internet is now a social reality.

Not a technological playground anymore.

Has society treated well our technology?

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FEATURE	Disruptive TREND
Distributed architecture	Next Generation Networks (3GPP) Mass entertainment
End-to-end characteristic	Self –Management Middleboxes
Openness	Political intervention Critical infrastructure provision Network neutrality
Technology neutrality	Web/service adaptation Bandwidth requirements Access Cost Sensors Wireless networks
Separate business and technology	Next Generation Networks Vertical clustering Regulation
Resilience	Lack of QoS

Recall slide for engineers

Our technology is now much more complex.

We are now a mobile society.

What can we expect in the future?

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The Path to My Mobile Future Internet

(very) Basic Trends in our (Mobile) world

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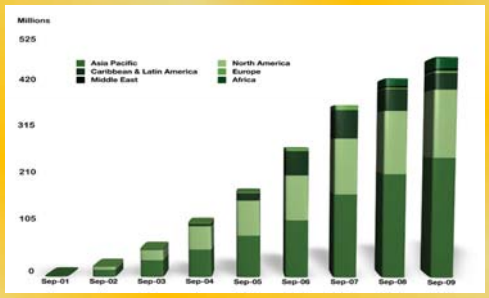
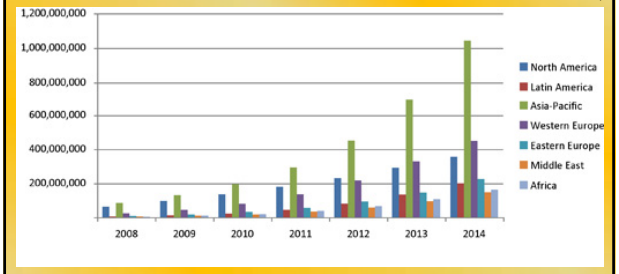
3G Subscriber Growth History

Today there are more than **500 million** 3G users worldwide
(out of 4 500 million GSM WCDMA(+++) subscribers)



Mobile Broadband Subscribers Forecast

Source: Informa



Integrated Future Mobile Networks

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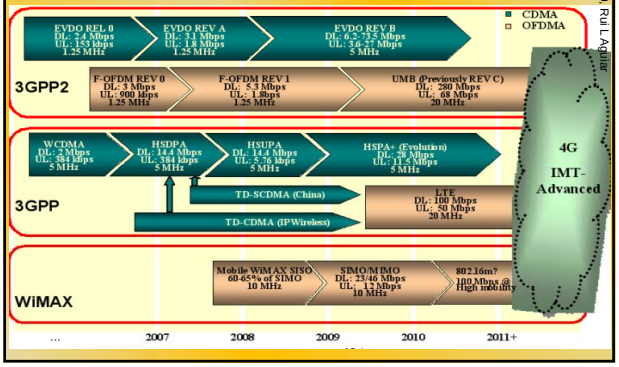
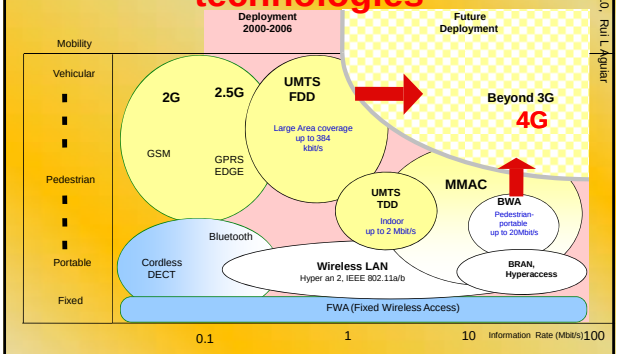


Evolution of mobile technologies



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4G networks

A 4G system (a Future Internet system?) will be able to provide a complete converged solution where voice, data and streamed multimedia are provided to users on an "Anytime, Anywhere" basis.

Data rates should be dynamic, resorting to the “always best connected” paradigm,

with **IP technology** as a common denominator between all of them.

What will the *(mobile?)* network of the future (*4G*?) be?

- Will the network nodes still require the same communication capacities?
  - E.g. Will we have cell phones as the major terminal?
- Will communication sources and sinks still be the same?
  - E.g. With sensors, cars and packages connected?
- Will the usage of the devices remain the same?
  - E.g. If M2M is common?

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well, I do not even know what the mobile network is becoming today ….

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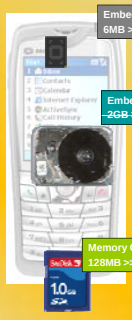
A Mobile Storage Revolution …..



Embedded Flash
6MB >>> 128MB

- Small size to minimise handset cost
- Used for storing system data: applications, messages, contacts, ring-tones

Embedded HDD
~~2GB >>> 50GB~~

- Large storage for user content
- But high impact on terminal cost

Memory Card
128MB >>> 16GB

- Large and removable storage for easy transfer of user content
- Interoperable with other consumer electronic devices
- Provides a distribution channel for selling content

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New interfaces

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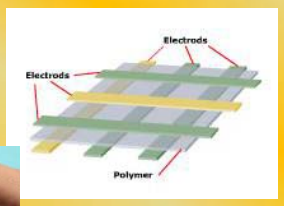
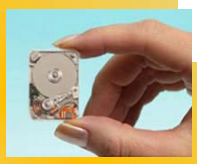
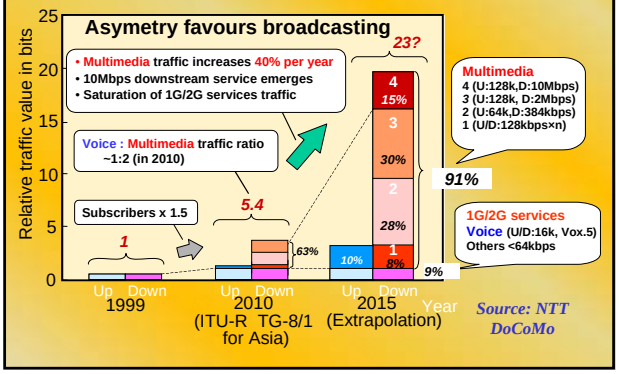
The Emergence of Local Information



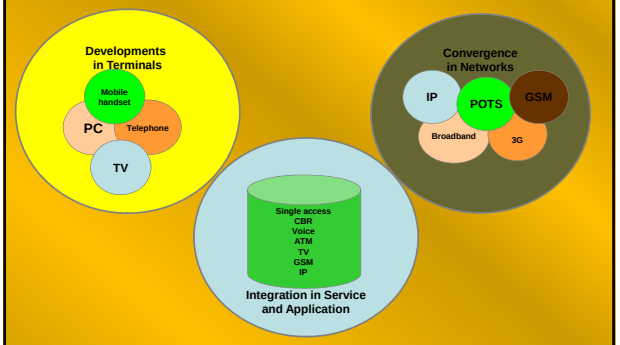


New virtual connections

Forecasted Traffic



Where is evolution taking place?



FI: Grandparents?

Local Area Networks

(multiple systems shared by a computer network)

Mobile Networks

(communications everywhere)

Broadband

(increased access bit rates, triple-play services)

Web

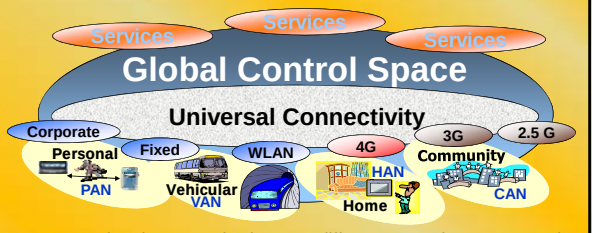
(Internet-style service access everywhere)

FI: Academic track record

- B.Sc on technology
  - Increased capabilities on devices
  - Increased reliability on transmission
  - Novel protocols for wireless and wired communications
- M.Sc on money
  - Cut-throat competition in the public arena
  - Lower profitability margins
  - Pressure for improved resource efficiency
  - Reduce OPEX
- Ph.D on society
  - Information-oriented society
  - …… government
  - …… economy
  - User and society as evolution customers… and drivers

Network is now more than bits and bytes – it adapts to where/what/who the users are

Future Mobile Internet – global networking



- Seamless interoperation between different types of access networks - mobile, fixed, local, personal
- A **common control plane**, implemented in all terminals and network elements
- Hides complexity of co-existence of multiple technologies and network types
- Enhanced and simplified **end user experience**

New Mobility Challenges

- Mobile architectures are no longer simply moving the terminal around.
- Mobility now:
- Is across technologies
- Is intelligent
- Is performed at the best level of the communications stack
- Is fully controlable, and fully in accordance with profiles
- Has multiple grouping variants (single node, multiple nodes, networks, ad-hoc)
- Is integrated with “everything else”

Let´s check some (US) examples…

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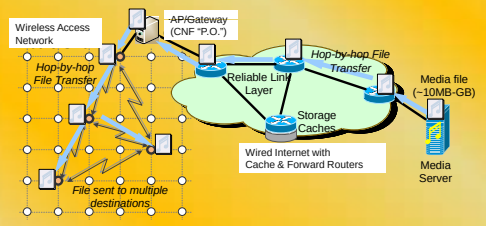
Clean Slate Project: Cache & Forward (CNF) Architecture

- NSF FIND “postcards from the edge” project at Rutgers & UMass (2006--)
- Architecture designed to optimize efficient delivery of content to mobile users, but works well for both wired and wireless devices
- Concept based on hop-by-hop transport, storage and caching in the network



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Named Data Networking

- **Who**: UCLA, Colorado State University, PARC, University of Arizona, University of Illinois/Urbana-Champaign, UC Irvine, University of Memphis, UC San Diego, Washington University, and Yale University
- **Covers:**
  - support secure content-oriented functionality, regardless of the specific physical location where the content resides.
  - Architecture centered in data
  - NDN secures the content and provides essential context for security.
  - decouples trust in data from trust in hosts and servers, enabling trustworthiness as well as several radically scalable communication mechanisms, for example, automatic caching to optimize bandwidth and the potential to move content along multiple paths to the destination.
  - technical challenges in creating NDN: routing scalability, fast forwarding, trust models, network security, content protection and privacy.

Clean Slate Project: Geometric Stack for Location Aware Networks

- Location-aware architecture project at Rutgers WINLAB (FIND, 2006--)
- Intended to study impact of location on future Internet protocols
- Evaluation of alternative methods, e.g. overlays vs. integrated layer 3, etc.

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MobilityFirst

- **Who:** Rutgers University/New Brunswick, Duke University, Massachusetts Institute of Technology, University of Massachusetts/Amherst, University of Massachusetts/Lowell, University of Michigan, University of Nebraska/Lincoln, University of North Carolina/Chapel Hill
- Covers
  - architecture centered on mobility as the norm, rather than the exception.
  - generalized delay-tolerant networking (GDTN) to provide robustness even in presence of link/network disconnections. GDNT integrated with the use of self-certifying public key addresses provides an inherently trustworthy network
  - context--and location--aware services to fit naturally into the network.
  - tradeoffs between mobility and scalability
  - opportunistic use of network resources to achieve effective communications among mobile endpoints.

eXpressive Internet Architecture

- **Who:** Carnegie Mellon University, Boston University, University of Wisconsin/Madison
- New network use models
  - Trustworthy communications
  - Larger number of stakeholders
  - New API
  - intrinsic security in which the integrity and authenticity of communication is guaranteed.
  - user experiments to evaluate and refine the interface between the network and users
  - relationships between technical design decisions, and economic incentives and public policy.

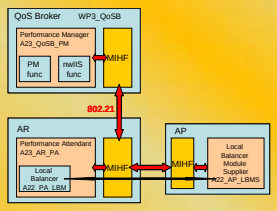
And one european view…

MARQS	▪ Integration of **M**obility Management, **A**uthentication, Authorization, Accounting, Auditing and Charging (A4C), with **R**esource Management, **Q**uality of Service, **S**ecurity and Privacy for support of end-to-end services across heterogeneous network technologies
VID	▪ **V**irtual **ID**entity concept to enable privacy through anonymity and unlinkability protection along the whole protocol stack ▪ Virtual Identities – personalisation at all levels – full user mobility
USP	▪ **U**biquitous and **S**eamless **P**ervasiveness: service availability independent of the network technology, device architecture, service type and user location.
SIB	▪ IP-based **S**eamless **I**ntegration of **B**roadcast, including group and multicast communications ▪ Addresses technology integration and provisioning of traditional broadcast services
Federation	▪ Dynamic, multi-party business environment between autonomous administrative domains for vertical and horizontal federations

IP Daidalos II

One small detail: Intelligent mobility

- Performance Management
- Network Initiated Handover
- *Redistribution of active flows*: This occurs after a network context change if the performance management blocks of the network realize that one or more flows can be assigned to a different PoA so that the network load can be optimized



Some challenges for FI

- To live in a complex, dynamic, mobile world
  - in types of services
  - In types of business actors
  - In numbers of services
  - In numbers of actors
- From the point of view
  - Multiply connected users
  - Multiply peered operators
- And provide
  - Optimum service
  - At optimum cost
  - With reliable and trusted behaviour
  - With **full mobility – user, terminal, service**

The major trends at a glance: Internet meets mobile

- Advance of the Internet
  The Internet has become a mass medium and IP the leading network protocol.
- Advance of mobile communication
  Communication via mobile radio networks is still increasing enormously.
- Bandwidth evolution
  The available bandwidth is exploding and the prices for bandwidth decrease dramatically.
- Reduced cost/bit
  Transmission OPEX has to come down to the commodity level.

And still more trends to cope with…

- Convergence of digital industries
  The converging digital industry brings together parts of the broadcasting, consumer electronics, communication, information technology, media and entertainment industries.
- Deregulation and globalization
  The ICT markets move fast.
  Competition and differentiation are driven by deregulation and globalization.
- Advance of society relevance
  E-commerce, e.g., changes and amends business processes tremendously.

Conclusions

- "Future Internet" will be mobile, mobile, mobile
- "Future Internet" will be **society-driven**
  - Technology will have to cope!
- Regardless of the "Post-IP" studies…
  - FI will be IP based for long time
    - Think how to incrementally improve it.
  - And we will know it as a "4G network"

And still we will have a complex network to plan, manage, control

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