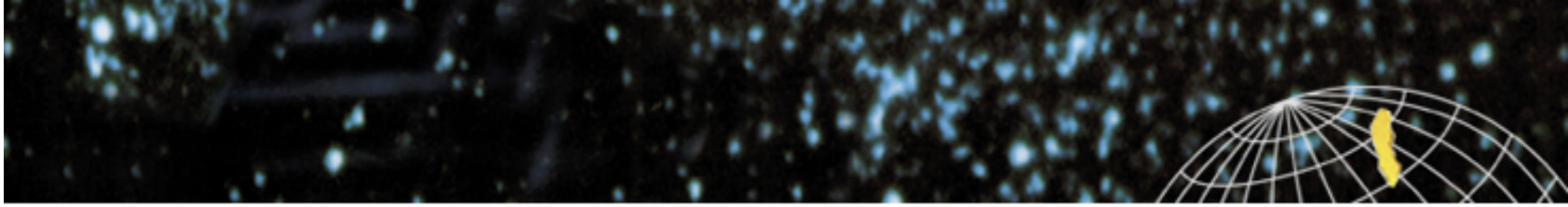


School of Information and Communication Technology

Wireless Communication beyond 3G – trends & challenges

Jens Zander

Director

Wireless@KTH

Wireless@KTH Center for Wireless Systems

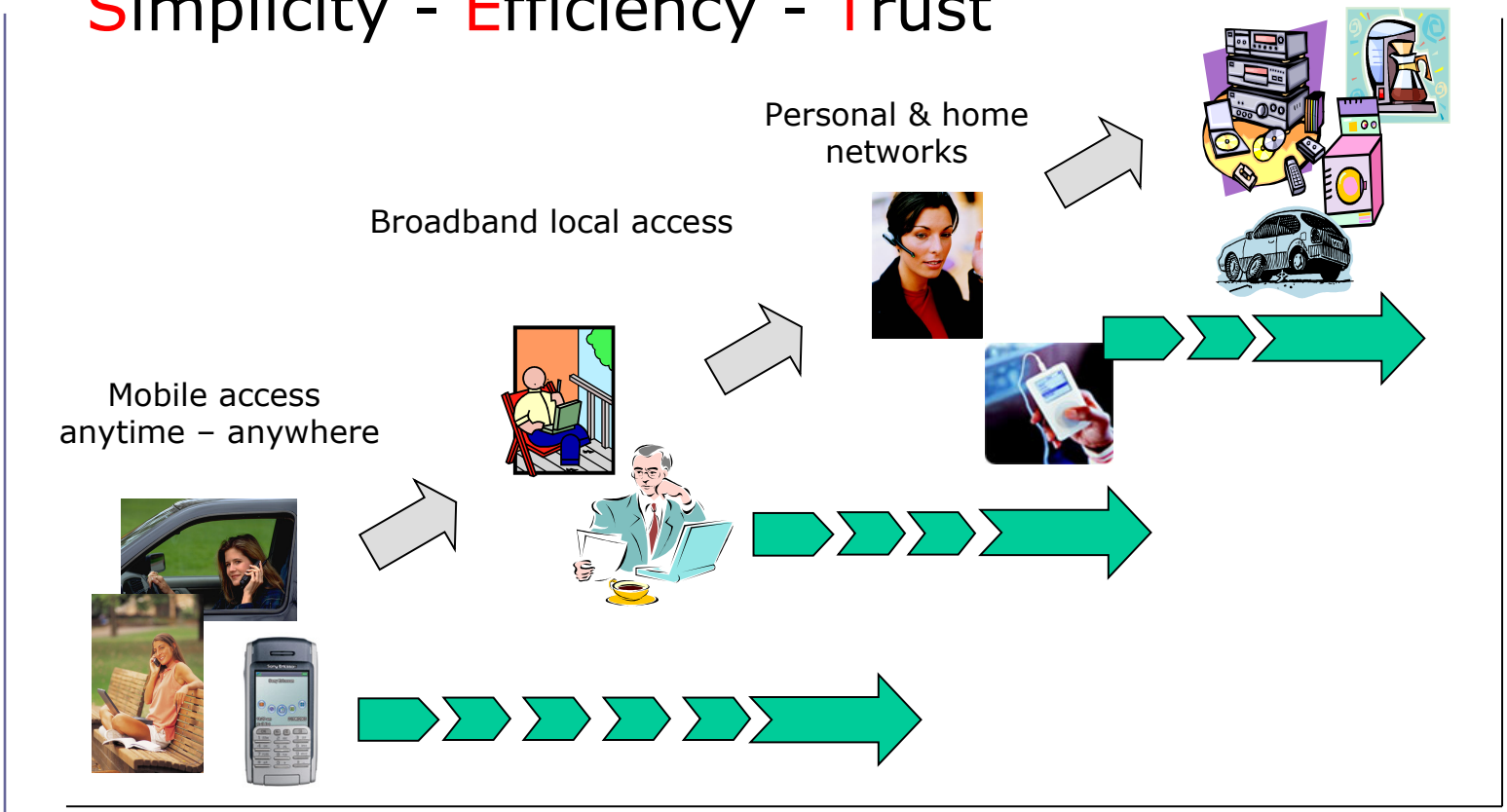
The wireless evolution

The Vision

School of Information and Communication Technology

"Things that communicate"

Simplicity - Efficiency - Trust

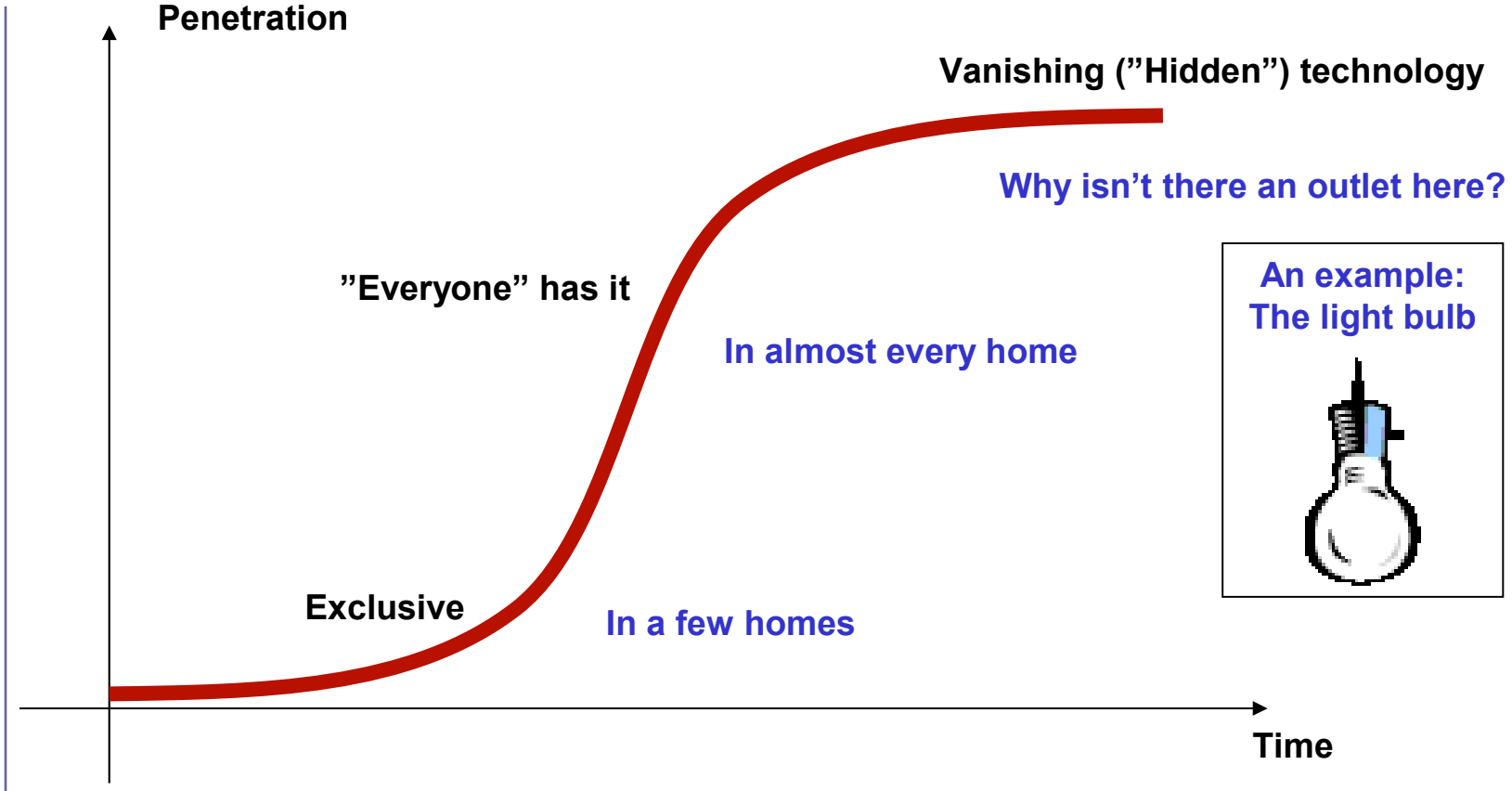


Mobility → Convenience, simplicity, low cost

Wireless@KTH Center for Wireless Systems

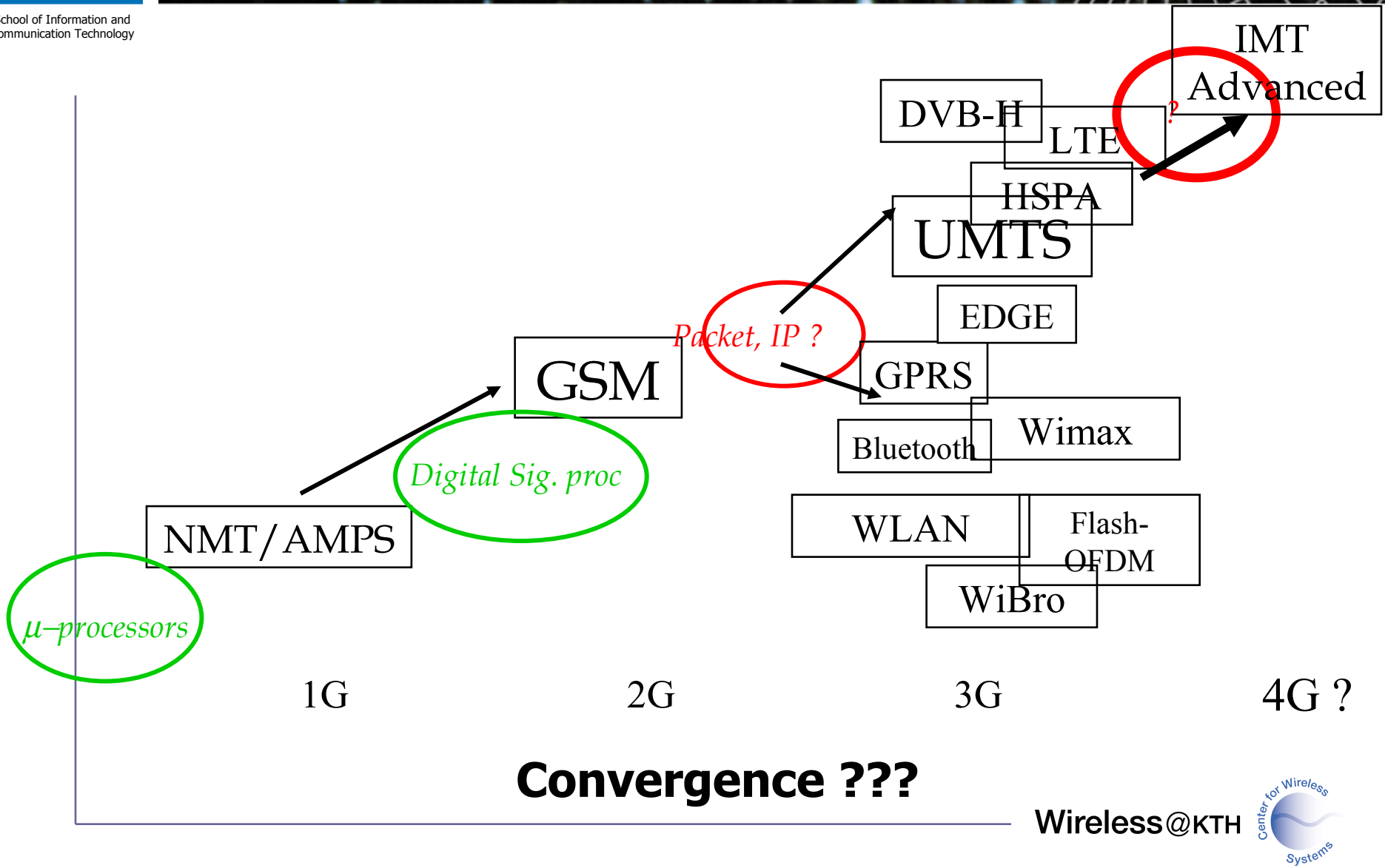
The Long term Vision: Wireless - A "Disappearing" Technology

School of Information and Communication Technology



Wireless Access Technologies – Playing the Generation Game

School of Information and Communication Technology



Wireless@KTH

Center for Wireless Systems

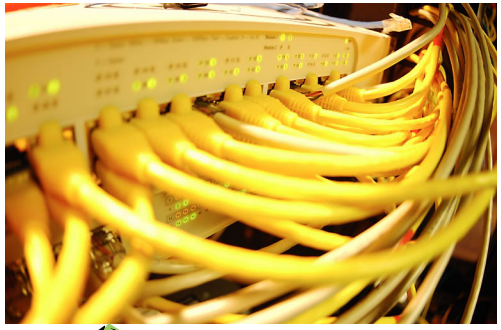
The challenges & potential - ”showstoppers”

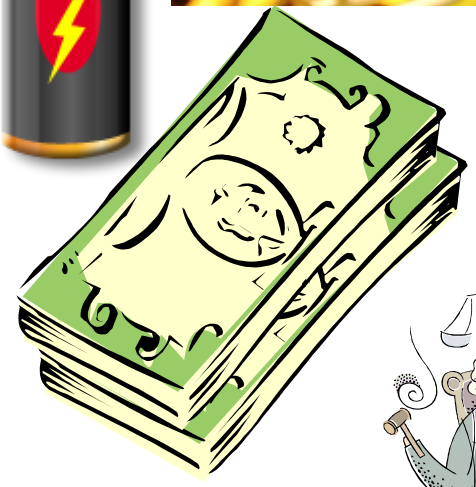
School of Information and Communication Technology

- Complexity – Reliability
- Energy
- Cost
- Legal issues ?
- Spectrum ?
- Shannon ?

Some solution trends

- Heterogeneous networking
- Reconfigurability



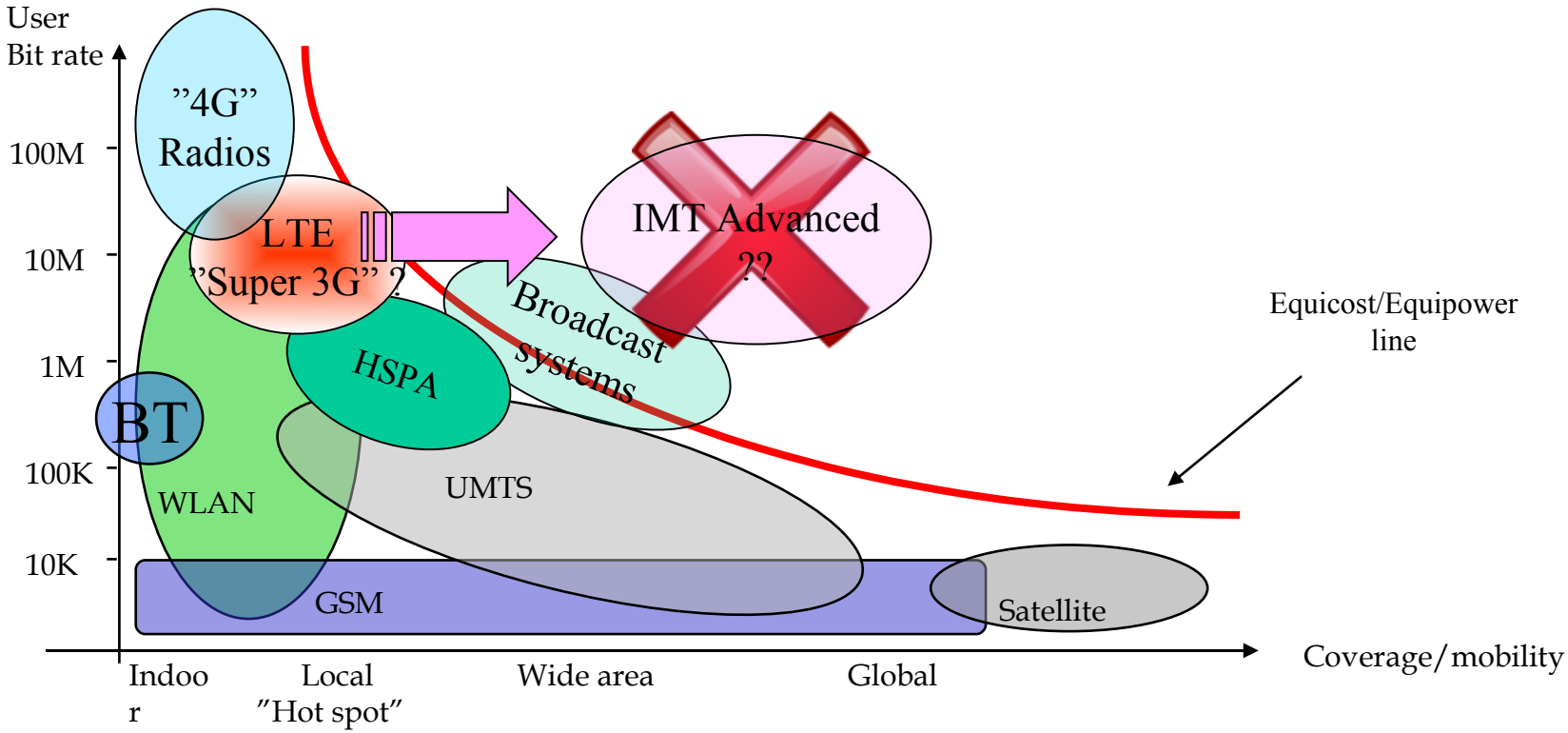


Wireless@KTH

Center for Wireless Systems

It's not (only) about bit rates

School of Information and Communication Technology



- New radio technologies no direct replacement for 2/3G systems
- Data rate not mainly limited by technology – but by deployment density
- Do we need more access technologies ?

Wireless@KTH Center for Wireless Systems

Affordable infrastructure - The 4 cost drivers

- High bandwidth
- Wide Area
- High speed mobility & lossless handover
- Real time/low delay

$$\frac{C_{system}}{N_{user}} \propto B_{user} A_{service} f(Q)$$

Wireless Communication Technologies - some key challenges

The Vision

School of Information and Communication Technology

Yesterday

0.1-1.0 billion of users
Complex networks
Complex expensive devices

- Complex to use
- Does not scale

Tomorrow

10-100 billion of users and devices
Even more complex networks
Complex but ***in-expensive*** devices

- Simple to use and deploy
- Extremely reliable
- Affordable for everyone

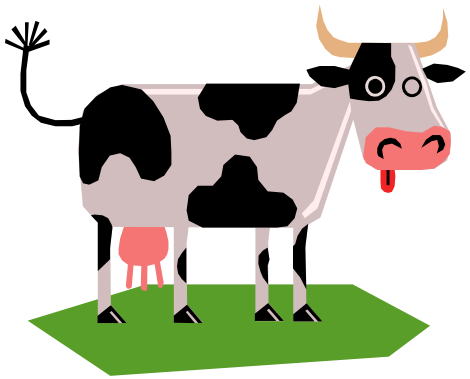
Some technology trends

Wireless Access: Todays paradigms

School of Information and Communication Technology

Anytime – Anywhere – Now !

- **Single system** for all needs
- Seemless, lossless mobilty required
- **Bandwidth/Capacity/Energy** are scarce resources
- **Spectrum is a scarce resource**
- Large volumes of devices needed
- Operators are needed to provide physical access
- Problems **can't** be solved by throwing bandwidth at them (cf. Fiber optic networks)
- The **wireless link IS the bottleneck**



The old dream: One system for all ?

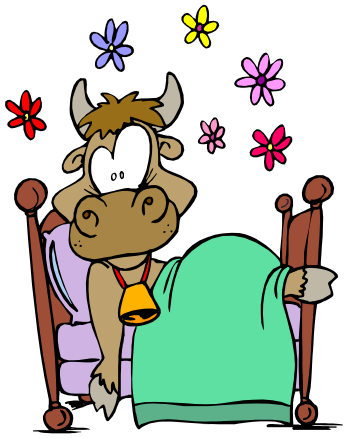
- Too different requirements
  - Not really good at anything
  - Cost determined by ”worst case” requirement
- Too complex system
- Not flexible enough
  - By the time its fully deployed its likely to be ”outdated”

School of Information and Communication Technology

Tomorrows paradigms

Sometime – Somewhere & <u>when</u> its cheap !
Local access – on premises, where people are, between things

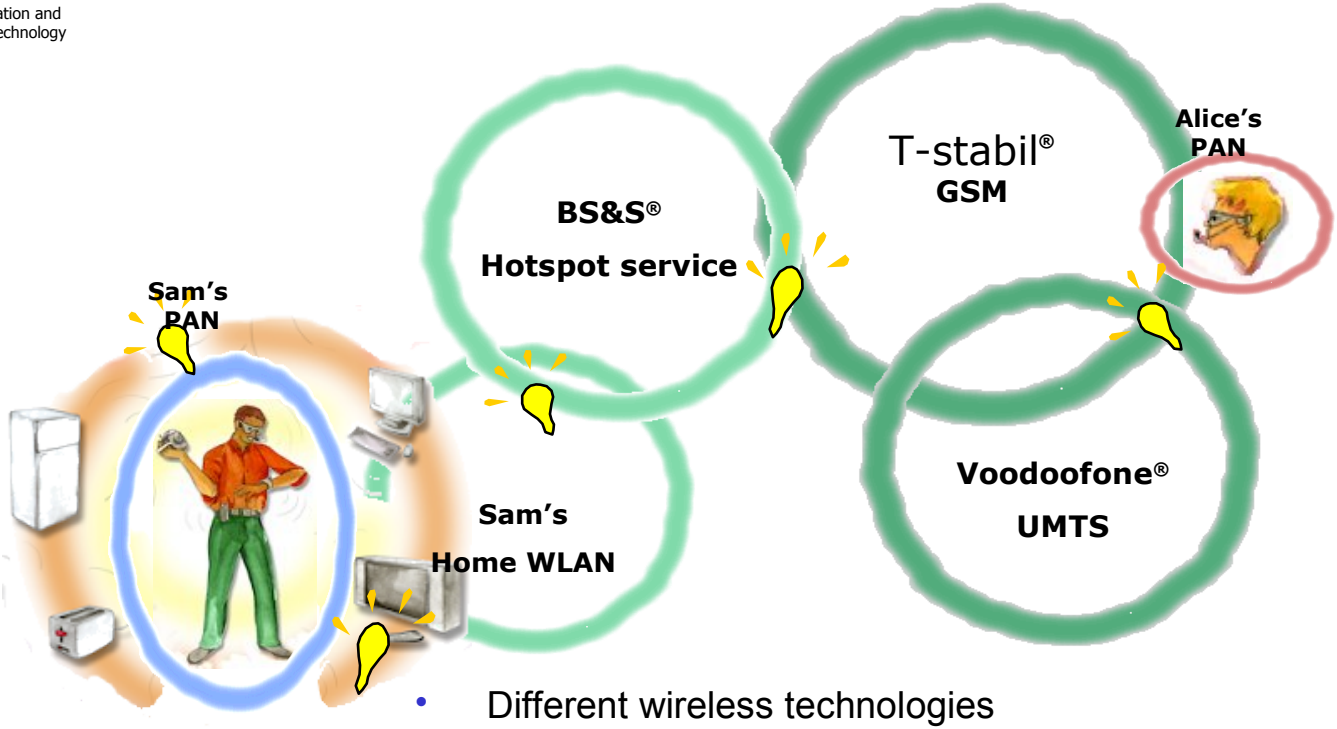
- **Bandwidth is <u>not</u> a problem**, latency & energy are
- **Storage is for free** – real-time consumption expensive
- High-speed, realtime HO not needed for ”seemless” connectivity
- Local access (< 50m)
- **Spectrum is abundant**
- Operators provide connectivity not necessary local wireless access
- Problems **<u>can</u>** be solved by throwing bandwith at them
- The wireless link is **NOT** the bottleneck



Wireless@KTH Center for Wireless Systems

Wireless Networks Everywhere….

School of Information and Communication Technology



- Different wireless technologies
- Competing business actors (competing for spectrum)
- Large potential cost benefits by infrastructure "sharing"
  - …but
- Will it be ***simple, affordable,*** and ***reliable*** enough?

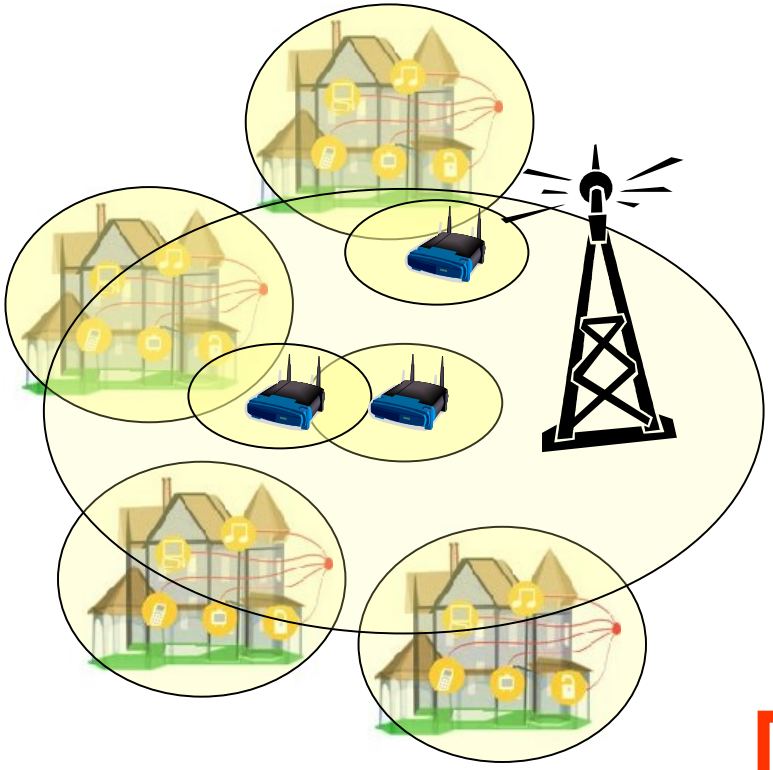
The convergence point – the multimode terminal

School of Informatic Communication Tech

GSM/GPRS/EDGE/WCDMA/WLAN/DVB-H
”Quadruple-band”

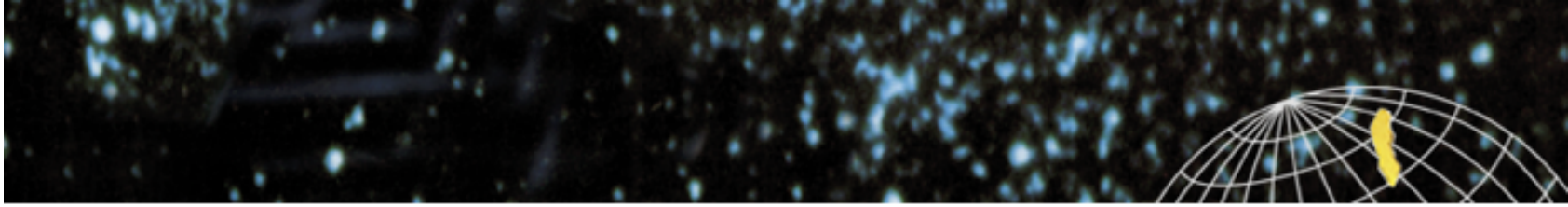
- Moore law works for electronics – not for physical infrastructures
- Life-cycles
  - Terminals: months-years
  - Infrastructure: years-decades
- Terminals will
  - ”always” contain the right mix of ”tools” and use the proper spectrum
  - Tailored to customer & application needs

The heterogenous future



- Many technologies – for each access:
  - Partial coverage – varying data rates
  - Rudimentary coverage in rural areas
  - Moderate reliability in each access
  - Limited QoS guarantees

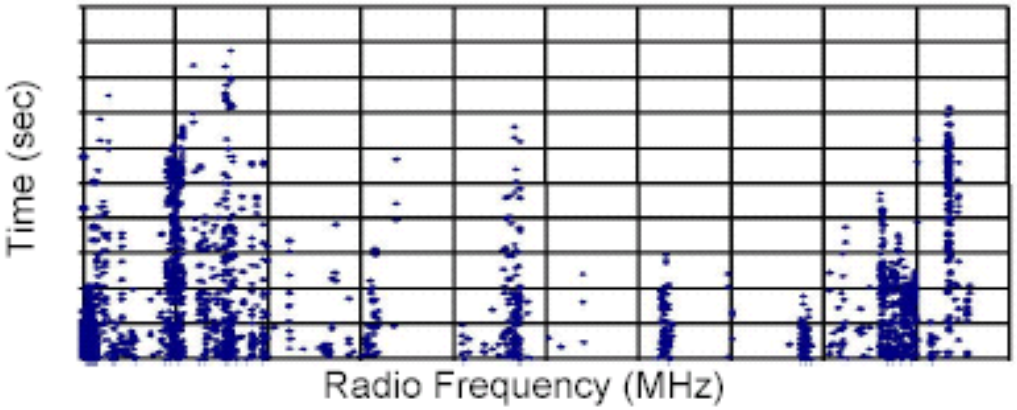
Reliability & Quality through system redundancy



Is there enough spectrum ?

Or is spectrum cheap enough ….

The spectrum – a scarce resource ?



- Large part of the spectrum (appears to be) unused
- Long time constants in (re-)allocation (decades)

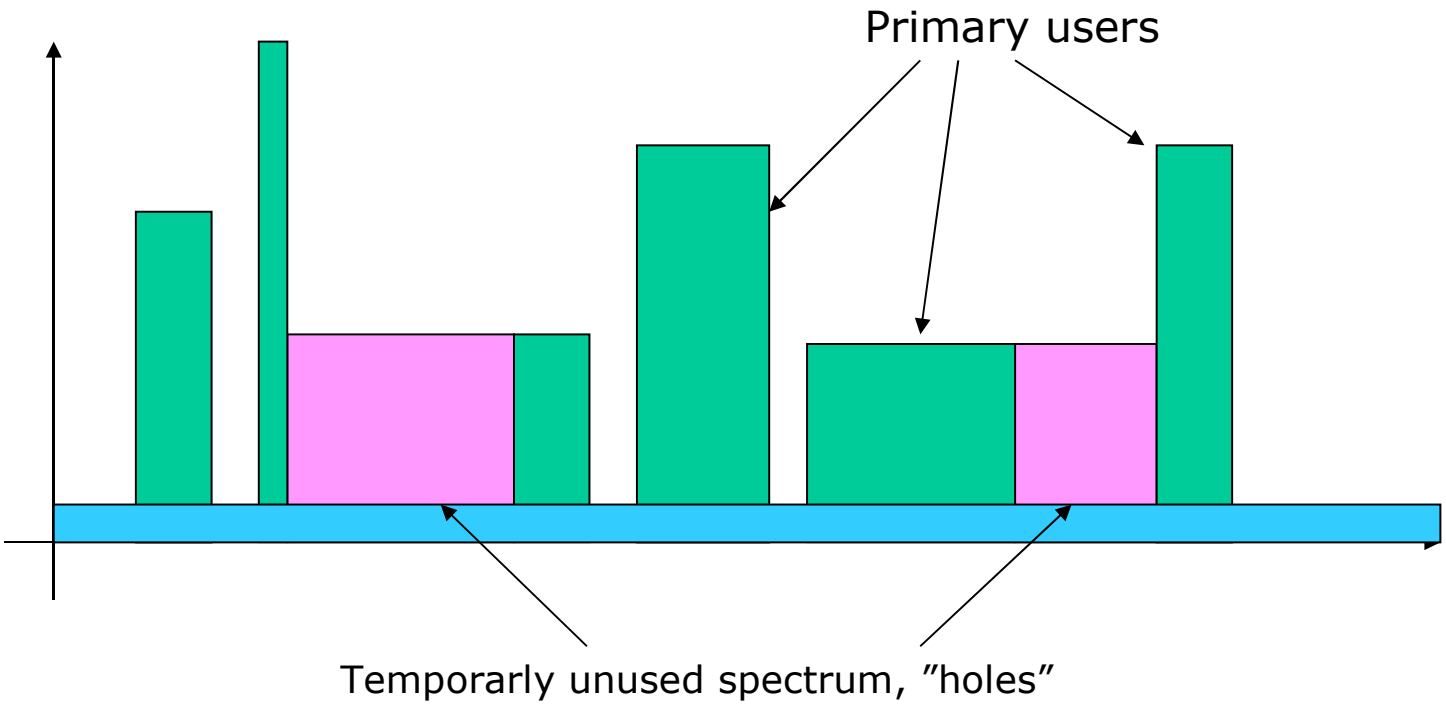
Access Limitation vs Throughput limitation ?

Figures from William D. Horne: "Adaptive Spectrum Access: Using the Full Spectrum Space", MITRE Corp.

Dynamic Access Modes

Opportunistic (Overlay) Access (”Cognitive Radio”)

Underlay Access (”UWB”)



Opportunistic& Wideband Access Technical potential & challenges

School of Information and Communication Technology

- Tomorrow's radios potential
  - Highly flexible – bandwidth, waveforms, frequencies
  - Built for a dynamic demand and a dynamic environment
  - Use the spectrum more efficiently!
  - Most of the technology already exist

- Research challenges
  - Dynamic non cooperative interference control!
  - Technical mechanisms for real time trading
  - Flexibility vs. performance trade-offs (radio design)
  - System integration and regulation must fit together!!

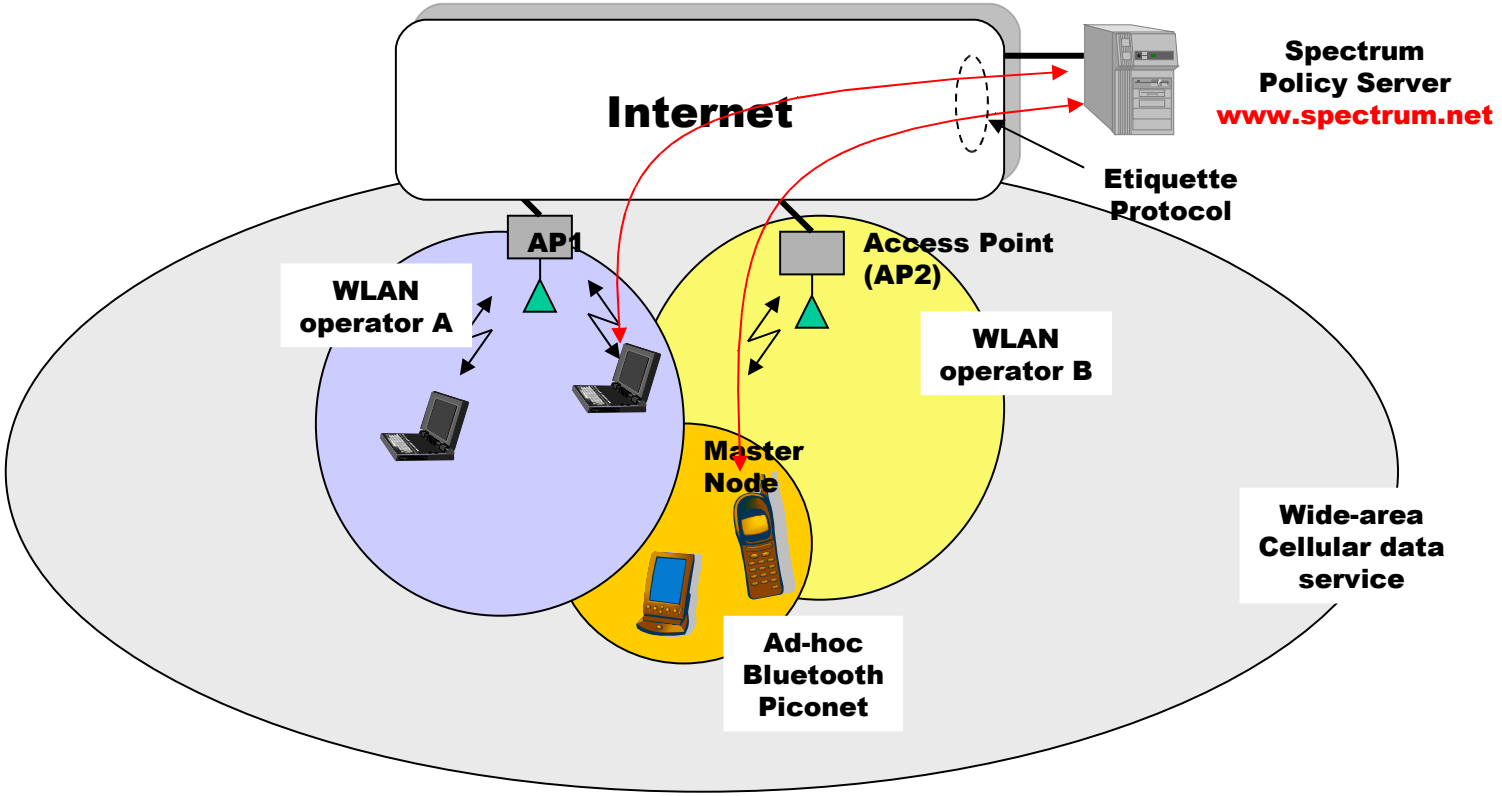
Future proof solution ?

- What happens when all are either scavenging for spectrum or "hiding in the noise" ?

Wireless@KTH Center for Wireless Systems

Spectrum policy servers
”Traditional spectrum management on steroids”

School of Information and Communication Technology



Source: Wade Trapp, ”Cognitive Radio Research in the U.S.: Overview, Challenges and Directions” WINLAB, Rutgers University, June 2007

Software Defined Radios ?

- Do we need Software Defined Radios ?
  - How many waveforms are needed ?
  - Backwards compatibility – but future proof?
  - Analogy – PC, Household appliance
- How flexible does it get ?

  Washing machine: 1 Gflop/event

  Computer game: 20 Mflops/event

  Router (100 Mbit/s): 25 Kflops/event (IP packet)

  SDR (100 MHz BW): 5 flops/event

Conclusions

- Shannons law
  - wide area broadband access will be expensive
- Heterogeneous wireless networking
  - making the most out of combinations of existing and new (sparse) high speed access networks
- Spectrum is NOT a limiting factor
  - But spectrum access is
  - More spectrum – more affordable systems

www.wireless.kth.se

School of Information and Communication Technology