



# Low cost wideband access – Key Research Problems & Business Scenarios

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## Or.. The future of Wireless Access - a European perspective



Views presented are my own and not necessary those of the European Commission, WWI projects nor other project partners

# WWI Partners



- Manufacturers
  - Alcatel
  - DaimlerChrysler
  - Ericsson
  - Lucent (UK)
  - Motorola (France)
  - Nokia
  - NEC (Germany)
  - Panasonic (Germany)
  - Philips
  - Siemens
  - ....
- Operators
  - BT
  - DoCoMo (Germany)
  - France Telecom
  - Vodafone
  - Telecom Italia
  - TeliaSonera
- Universities & Research Institutes
  - Aachen Univ, TU Berlin, Budapest TU, U Cantabria, Chalmers Univ, ETH (Zurich), U Ferrara, Fraunhofer Inst, KTH, SICS, TNO Telecom, UC London, U Surrey, VTT...

# Mobile Data - the road to success ?

- Fixed internet:
  - Web-browsing – the multimedia service platform
    - Interactive information services
    - Streaming audio/video
    - Rich exponentially growing content
  - Decent access data rates (xDSL, Cable etc)
  - **For free.... (flat rate..)**
- Same services for mobile
  - Adapted to small terminals
  - Location & context aware
- **Same price as mobile telephony ?**



# "The cellular breakdown"

- why is it so difficult get wide-band access anytime anywhere ?

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

- Shannon bounds & "last mile" physical infrastructure main limitations – not electronics, photonics, processing etc.
- Cost per user proportional to bandwidth provided
- The same users have to pay for more infrastructure

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

**Cost per transmitted bit virtually the same !**

# What are we going to do about it ?



**Breaking the cost barrier –  
Research challenges for the next decade**

# Breaking the cost barrier

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

- Sacrifice bandwidth/compatibility ? (Lower B)
- Sacrifice QoS guarantees (Lower f(Q) - delay, availability..)
- Sacrifice uniform coverage (Lower A)
- New architectures (Lower  $c_{AP}$ )

## Short term: Sacrificing bandwidth.... Mobility & Location dependent services

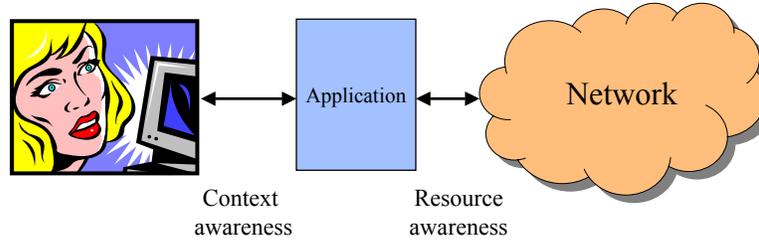
- Small wearable devices
- Limited I/O capabilities, Moderate data rates required (<100 kbit/s)
- Typical Services:
  - Messaging
  - Maps & directions
  - "Remote control"
  - Shopping & payment (e-cash)
  - Video clips
  - Games



.....but is this the "Mobile Internet" ?

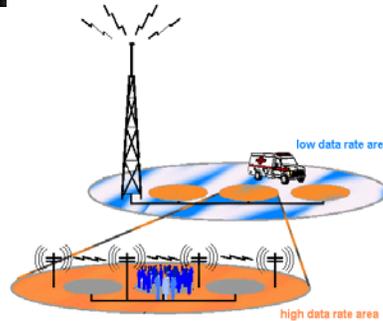


”Sometimes – Somewhere”



### Future coverage scenario:

- Points with extreme data rates (“Infostations”) > 1Gbit/s
- Areas with high data rates unicast (1-50 Mbit/s)
- Areas with moderate data rate (~ 100 kbit/s)
- Areas with wideband broadcast (>20 Mbit/s, e.g. DVB)
- Areas with (almost) no coverage



### Solution concept for “Interactive” entertainment services

- Massive memory terminals (~ 10-100GB)
- Smart personalized caching

“Moore’s law” works for memory – not physical infrastructure

**Wide Area Ambient Networks**  
making the most out of the heterogeneous wireless environment

The diagram illustrates a network of overlapping wireless environments. On the left, a blue circle labeled 'Sams PAN' contains an illustration of a man in an orange shirt and green pants. To its right is a green circle labeled 'Sams Home WLAN' containing a television and a laptop. Further right is a green circle labeled 'BS&S Hotspot service' with a lightbulb icon. To the right of that is a red circle labeled 'Alice's PAN' containing a woman's face. Below Alice's PAN is a green circle labeled 'T-stabil GSM' with a lightbulb icon. At the bottom right is a large green circle labeled 'Voodoofone UMTS' with a lightbulb icon. In the top left corner, there is a logo for 'Ambient Networks' with a large 'N' and the text 'Ambient Networks' below it.

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**The long term solutions:**

**Alternative infrastructure architectures**

The illustration shows a dark silhouette of a person standing on the left, reaching upwards with their right arm towards a teal rectangular area filled with yellow stars of various sizes. The background is a dark, starry space.

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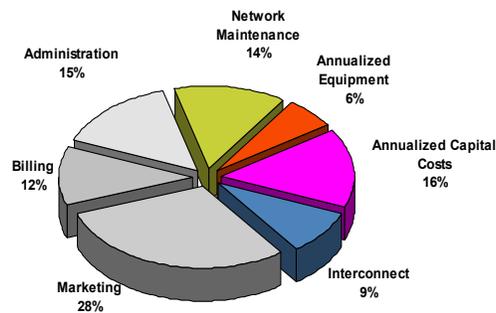
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# Low cost infrastructure ?

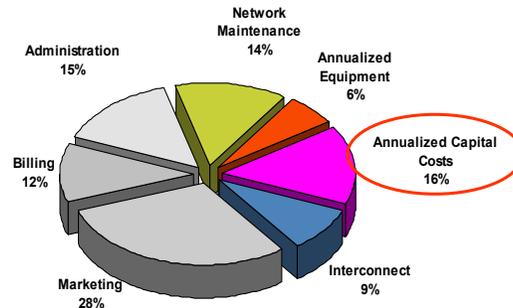
- Cost models for infrastructures
  - Breakdown to components & cost drivers
  - Focus of fundamental cost drivers – valid also tomorrow
- “New” engineering problem:
  - Given QoS, Coverage, Performance ...  
Design architectures that minimize cost
  - QoS - Cost tradeoffs
  - New objective function – most tools still usable

# Low cost infrastructure – cost analysis example



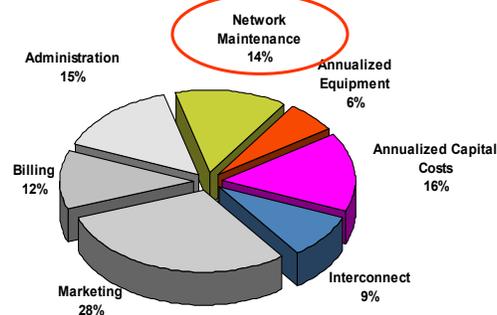
- Equipment small & decreasing part of operator cost
- Operation & Maintenance
- Site related infrastructure costs
- Transmission & interconnect

## Attacking infrastructure cost factors (1)



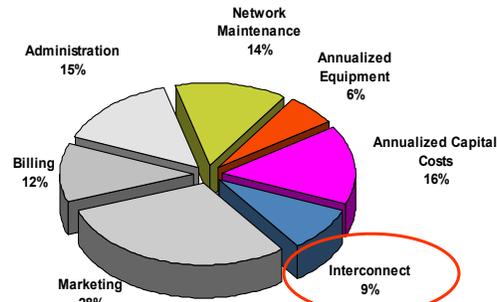
- Planning & deployment
  - Selforganizing
  - 0-configuration systems
- Site cost

## Attacking other infrastructure cost factors (2)



- Maintenance reduction
  - Massive user driven deployment
  - Large redundancy
  - No 24/7 maintenance required

## Attacking other infrastructure cost factors (3)

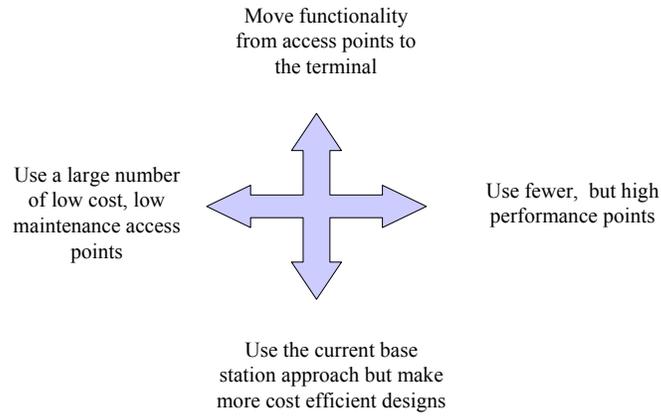


- Backbone:
  - Wireless link backbone
  - Multihop forwarding techniques
  - Reduce # of sites

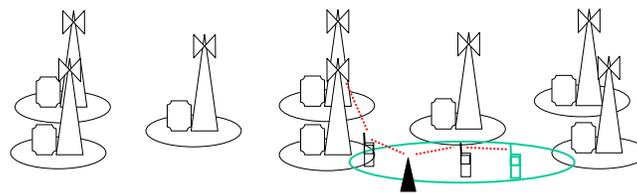
## Cost analysis – some important observations

- Equipment cost is not the dominant part of the overall network CAPEX or OPEX.
- The fraction of equipment cost to total infrastructure cost is likely to be reduced over time
- Site construction & deployment costs and rents are a major part of the network costs.
- Network maintenance costs are a significant

# Low cost infrastructure – possible research directions

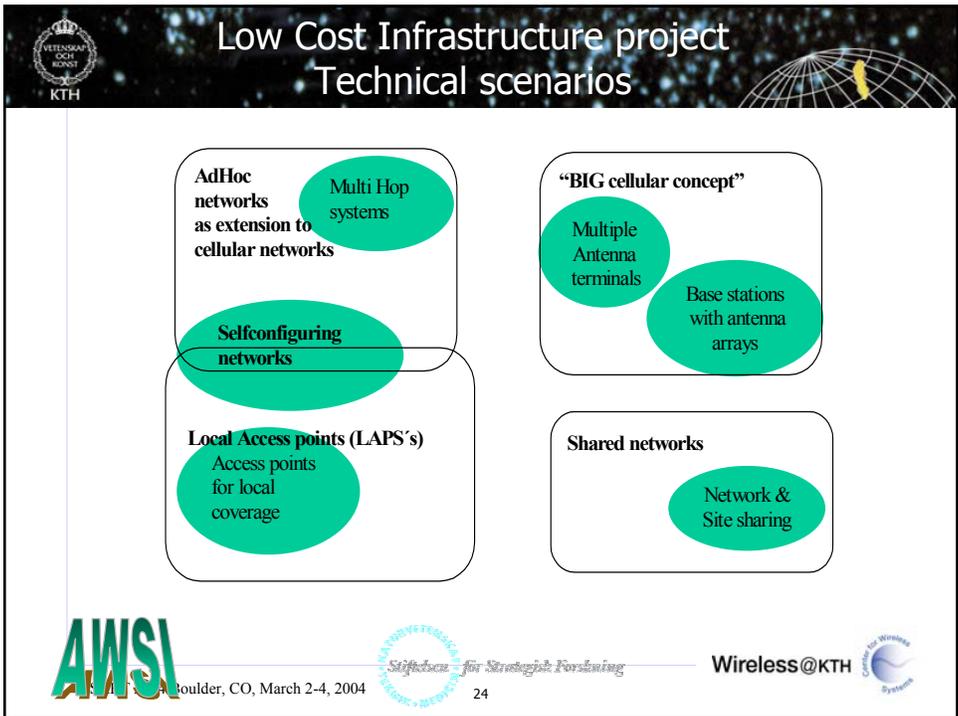
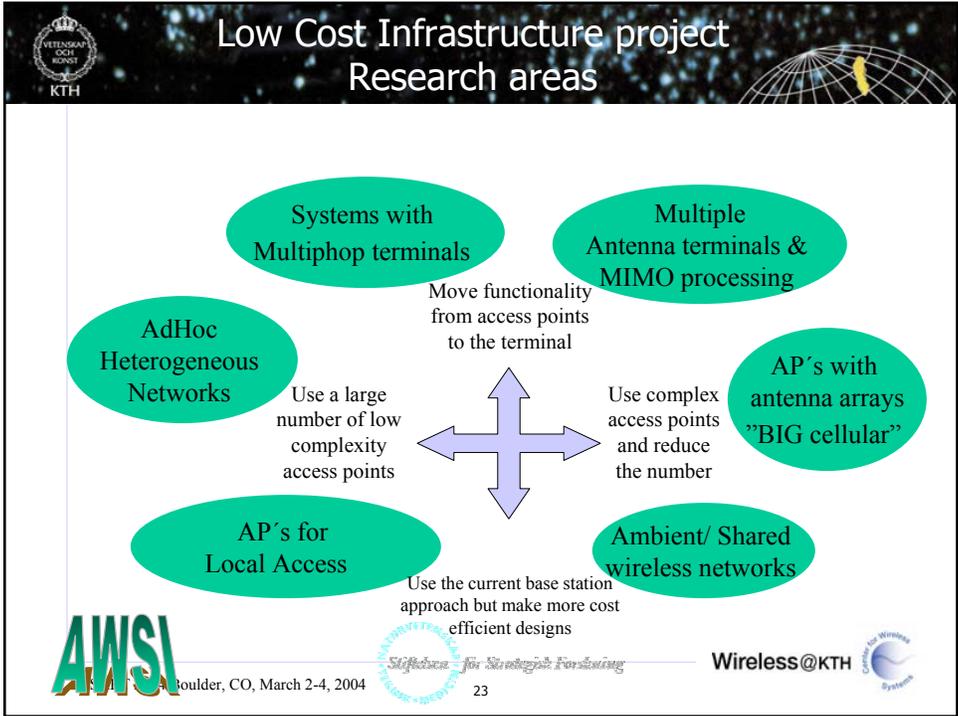


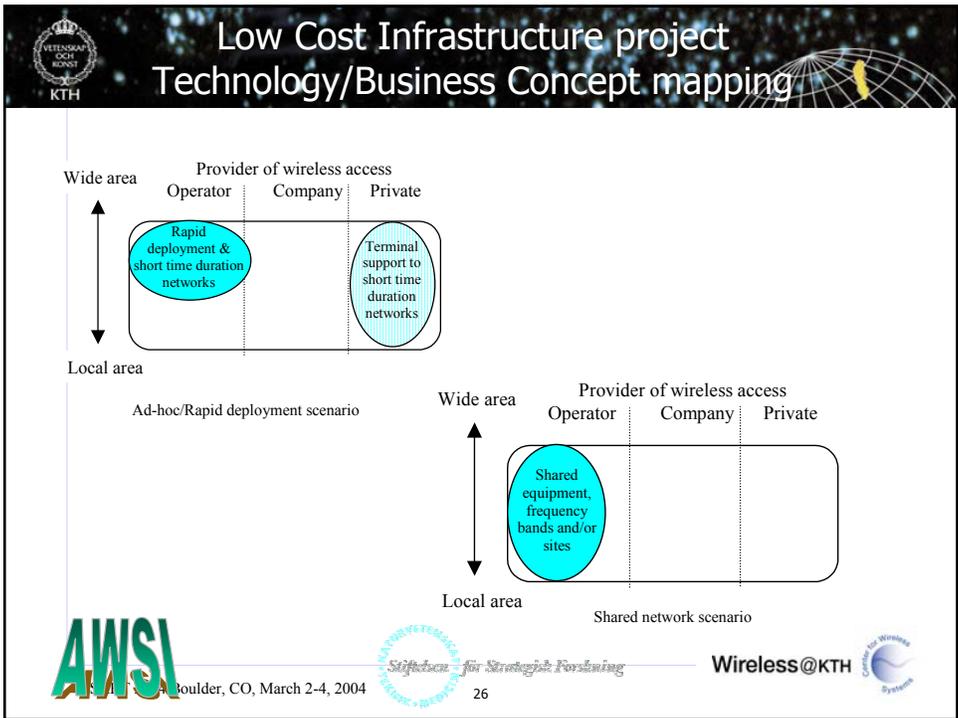
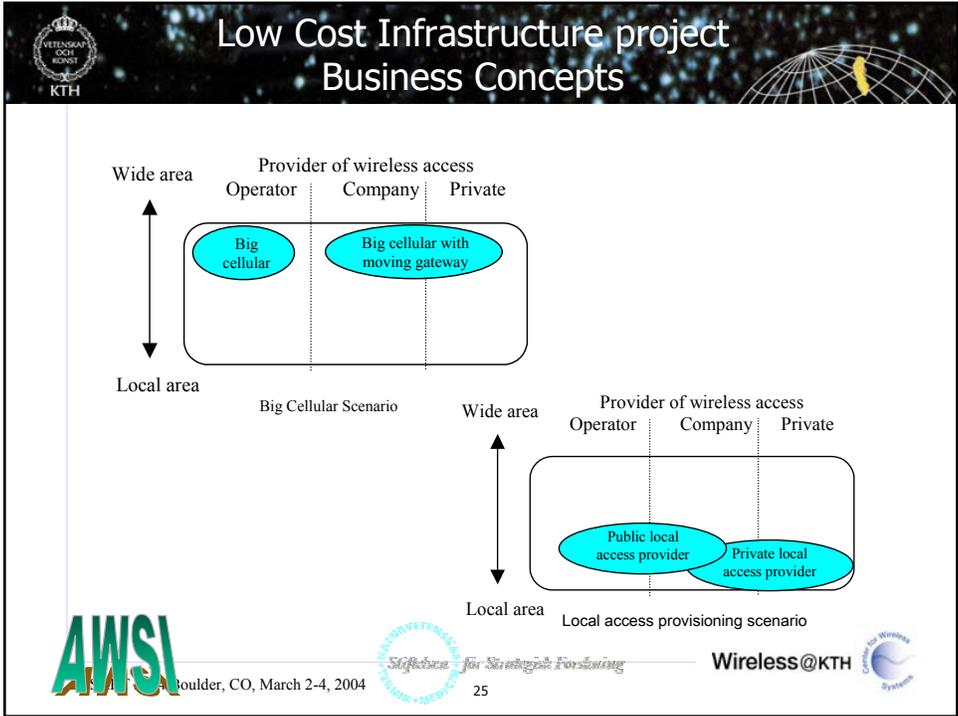
# More functionality in the terminals

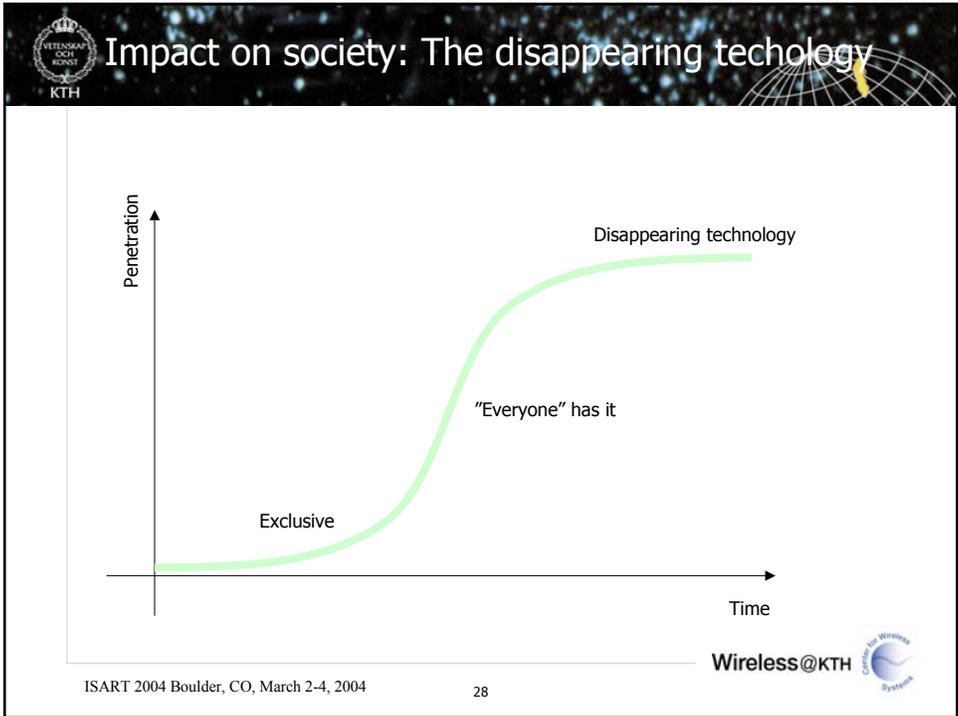
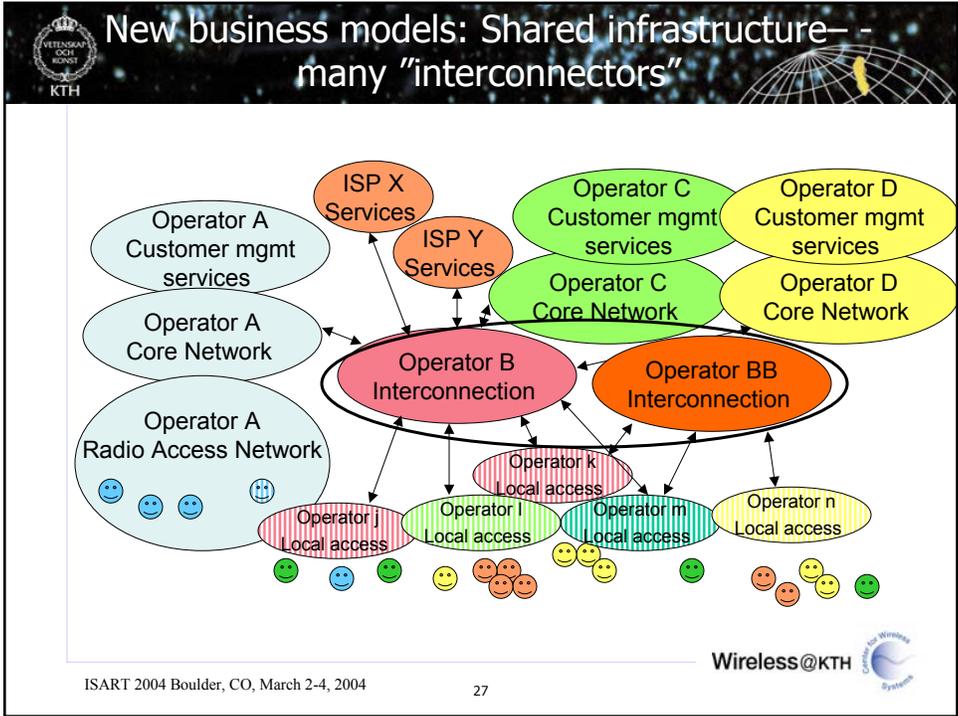


## Multihop range extension

- Multihop terminals
- Low cost wireless routers/"digipeaters"







## The base station of the future – my vision



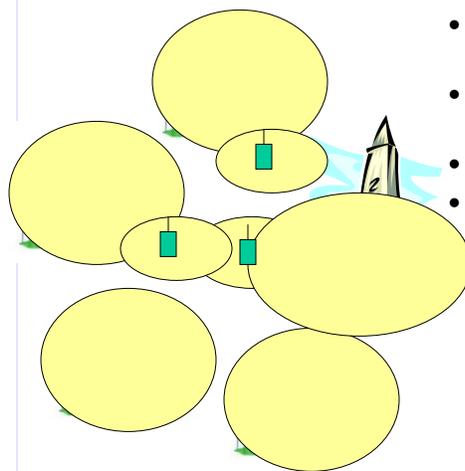
### Usability issues

- User deployable
- 0 - configuration
- Cheap – disposable (< 50\$)
- low/no maintenance

### Likely technical characteristics

- Direct IP interface
- Multihop capability
- Multi-purpose
- Access network roaming
  - Across air-interfaces
  - Across business boundaries

## The Infrastructure of the future – my vision



- Partial coverage – varying data rates
- Rudimentary coverage in rural areas
- Moderate reliability
- Limited QoS guarantees

- The base station:
  - from complex, industry grade, high reliability system to consumer products
  - Mass market commodity product (with low profit margin)
  - Increased capabilities (self-configuration, adaptation) increased hardware share of infrastructure expenditure
- The terminals:
  - Increased networking capabilities (multi-hopping, self-configuration)
- Key challenge:
  - Efficient business models require new payment schemes
  - Low transaction cost – anonymous (?)
  - Example: "Nano-payment" schemes (E. Noam 2000)

## Breaking the cost barrier

- Short term:
  - Low/moderate bandwidth, best effort applications for small terminals with limited I/O capabilities
- Medium term:
  - Adaptive, memory intensive applications providing interesting applications in "somewhere/sometimes" environments
  - Ambient/shared infrastructure solution exploiting legacy, evolved and new infrastructure components
- Long term:
  - New infrastructure architectures
  - Multihop, self-configuring, low-maintenance....



Read more!



**[www.wireless.kth.se](http://www.wireless.kth.se)**

**[mobile.wireless.kth.se](http://mobile.wireless.kth.se)**

Mobile device friendly!

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