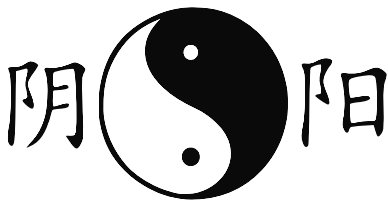


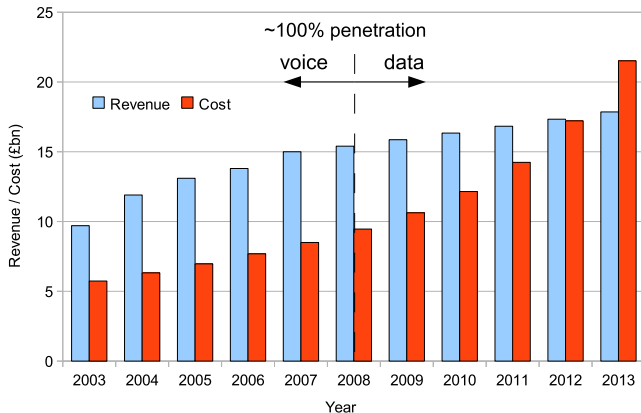
The Yin and Yang of Wireless Communications



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Mobile Telecoms Industry



Sources: Ofcom, "The communications market 2009," August 2009.
Cisco Systems, "Global mobile data traffic forecast update," January 2009.
Vodafone Group Plc., "Annual Report on Form 20-F," March 2009.

FILED UNDER [Cellphones](#), [Misc. Mobile](#)

AT&T to offer 'incentives' to customers willing to limit data usage

By [Donald Melanson](#) posted Dec 17th 2009 12:56PM

AT&T exec #1: You know, our network's really getting slammed with all these people using their unlimited data plans to download things and do stuff online all the time. Any ideas how we can fix it?

AT&T exec #2: We could put out more WiFi hotspots. People seem to use those. Sometimes.

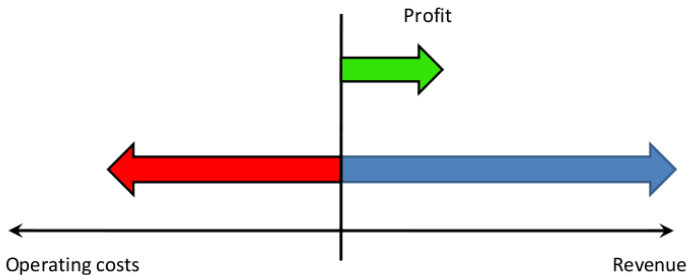
AT&T exec #1: Sure, but that's not going to make a dent in places like New York City. I mean, have you used an iPhone there?

AT&T exec #2: We have these things called [MicroCells](#) that people can use



at&t

Revenue is not Utility!

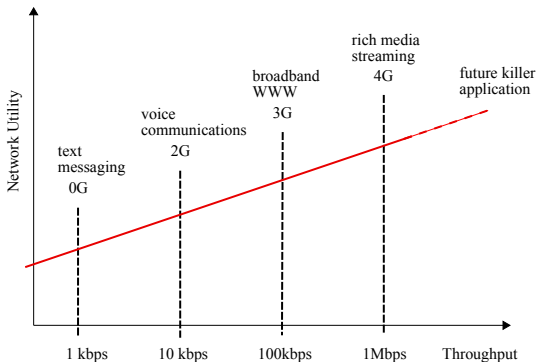


$$UTILITY = VALUE - COST$$

Datarate is not Value!

- Text Message
 - 12p for 160 bytes
 - 0.075 p/byte
- Voice Call
 - 18p for 60s x 6.7kbits/s
 - 0.000358 p/byte $\approx 100\times$ less then messaging
- Mobile WWW
 - £30 for 1GB per month @ 100kbits/s
 - 0.000003 p/byte $\approx 100\times$ less then voice
- Video Streaming
 - £1 for 60min x 1Mbits/s
 - 0.00000003 p/byte $\approx 100\times$ less then WWW

Value is a logarithmic function of Datarate!



Low of diminishing returns

$$VALUE = \alpha N_u \log \left(1 + \frac{R_u}{\tilde{R}} \right)$$

Efficiency versus Efficacy

Efficiency is a quality that characterizes the correspondence between the **utility attained** and the **costs incurred**.

$$\xi = \frac{UTILITY}{VALUE}$$

- A conventional incandescent light bulb is highly **inefficient**, since most (about 90%) of the consumed electric power is dissipated as heat rather than converted into the desirable product in the form of visible light.
- An LED device can be highly **efficient** at low current levels.

Efficiency versus Efficacy

Efficacy characterizes the correspondence between the **value attained** and a certain nominal **desirable outcome**.

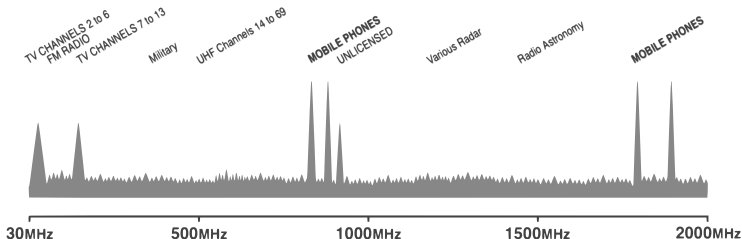
$$\zeta = \frac{VALUE}{VALUE_N}$$

- A conventional incandescent light bulb may be categorized as highly effective, since the objective of providing an adequate illumination may be readily realized.
- LED devices are typically inadequately **ineffective** for most mainstream lighting applications.

Efficiency of Communication Systems

- **Bandwidth Efficiency** is a **Datarate-to-Bandwidth Efficacy**
 - Potential increase in the bit-per-second-per-Hertz performance does nothing to reduce the costs associated with the process of data transmission.
 - In the vast majority of conceivable scenarios, the available bandwidth constitutes a fixed constraint.
 - The increase in the signal's spectral density is motivated by the sole objective of increasing the throughput.
 - No spectrum is actually consumed in the process of transmission of information.
- **Power and Cost Efficiency** constitute the only methodologically consistent definition of **Efficiency**.

Spectrum use in the PCS and Wi-Fi bands



- Spectrum is **neither scarce nor consumable**.
- Most of the available spectrum is under-used and the overall spectral efficiency is remarkably low.
- The effective cost of spectrum as resource is vastly inflated.

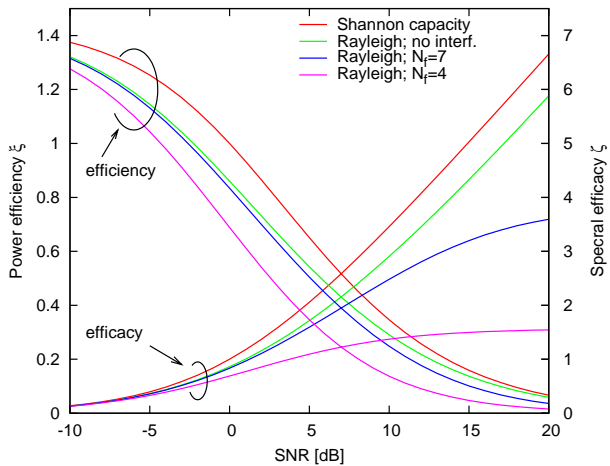
$$\begin{aligned}
 \text{UTILITY} &= \text{VALUE} - \text{COST} \\
 &= \xi \times \zeta \times \text{VALUE}_N
 \end{aligned}$$

$$\text{VALUE} = \alpha N_u \log \left[1 + \frac{B_u}{\tilde{R}} \log \left(1 + \frac{LP_u}{B_u N_0} \right) \right]$$

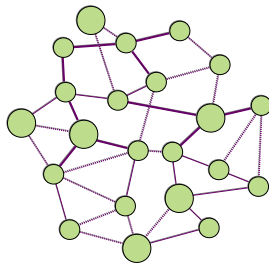
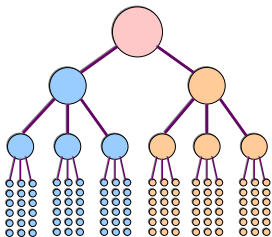
$$\text{COST} = \beta N_u P_u$$

$$\begin{aligned}
 \text{UTILITY} &= \alpha N_u \log \left[1 + \frac{B_u}{\tilde{R}} \log \left(1 + \frac{LP_u}{B_u N_0} \right) \right] - \beta N_u P_u \\
 &= \alpha N_u \log \left[1 + \frac{B_u}{\tilde{R}} \log \left(1 + \frac{LP}{BN_0} \right) \right] - \beta P
 \end{aligned}$$

Efficiency versus Efficacy



Cellular versus Ad Hoc



Serial versus Parallel



Heterogeneous Architecture of the Human Brain

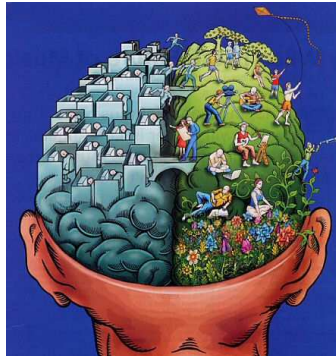
Left-Brain Functions

Analytical thought

Logic

Language

Science and math



Right-Brain Functions

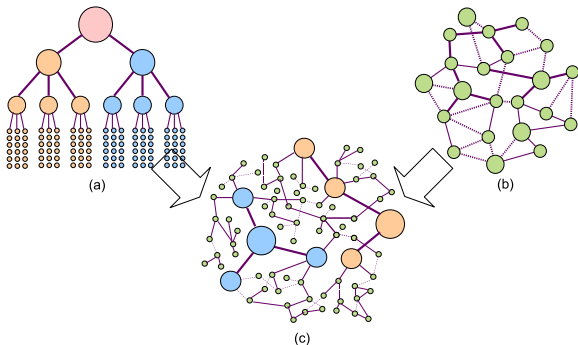
Holistic thought

Intuition

Creativity

Art and music

Heterogeneous Radio Access Network

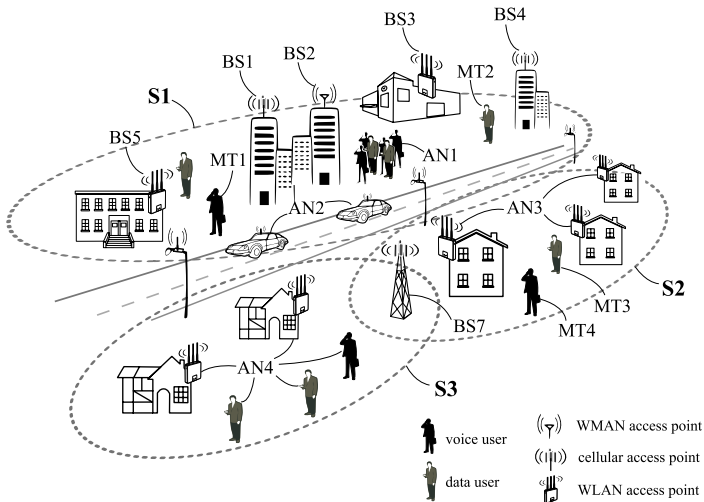


Cellular: scalable; highly dependable; designed to maximize **efficacy**

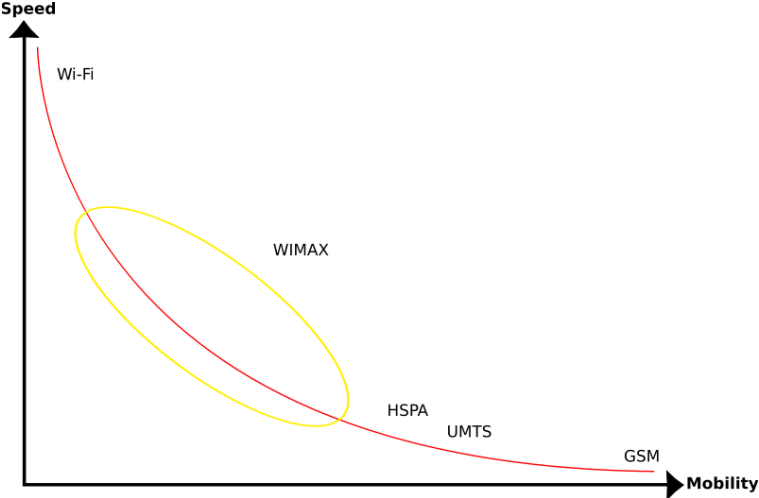
Ad hoc: flexible; self-organizing; designed for maximize **efficiency**

Heterogeneous: a fusion of **cellular** and **ad hoc** architectures, which attains the desired trade-off between **efficacy** and **efficiency**.

Mobile Flexible Network



Multimode Mobile Terminals



Multimode Mobile Terminals



Enabling technologies

- Multimode terminals
- Software-defined radio
- Cognitive radio

Key technological prerequisites

- Spectrum sharing
- User cooperation
- Adaptivity
- A unified air interface characterization methodology.

The Future Killer Mobile Application?

- 3D super-HD holographic immersive gaming
- bus timetable (seamless access to contextually relevant information)



Thank You!

