SAMSUNG ADVANCED INSTITUTE OF TECHNOLOGY

Green Networking

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2011.03.09

SAIT

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- Wireless Access (Wireless Base Station)
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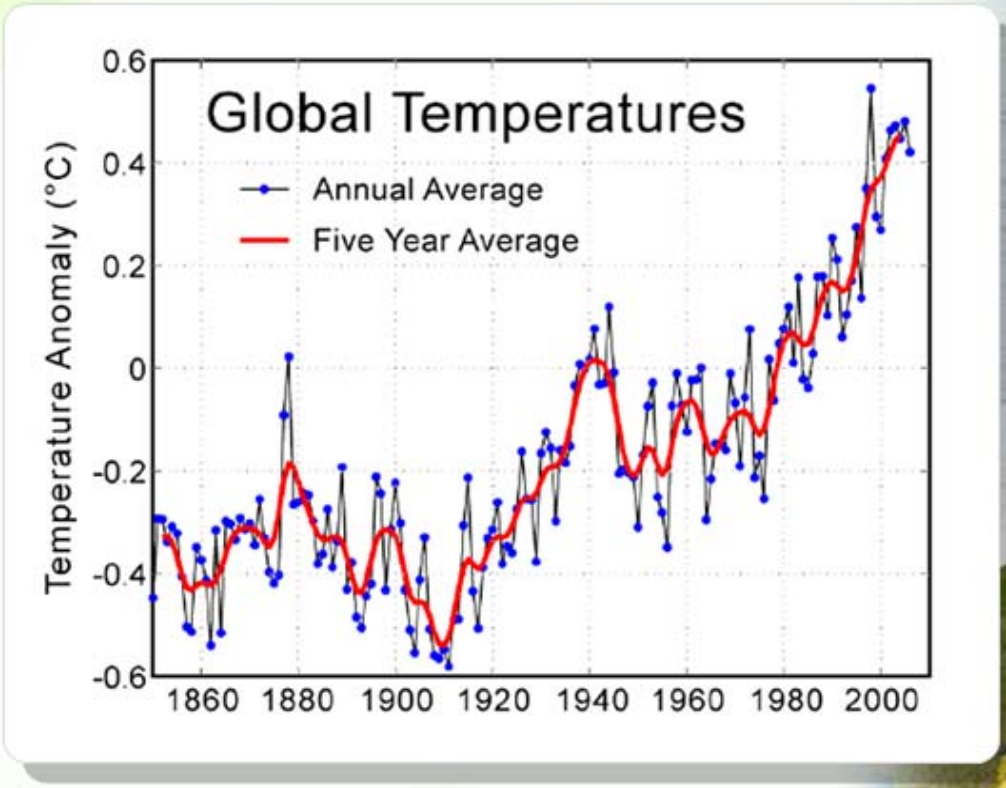
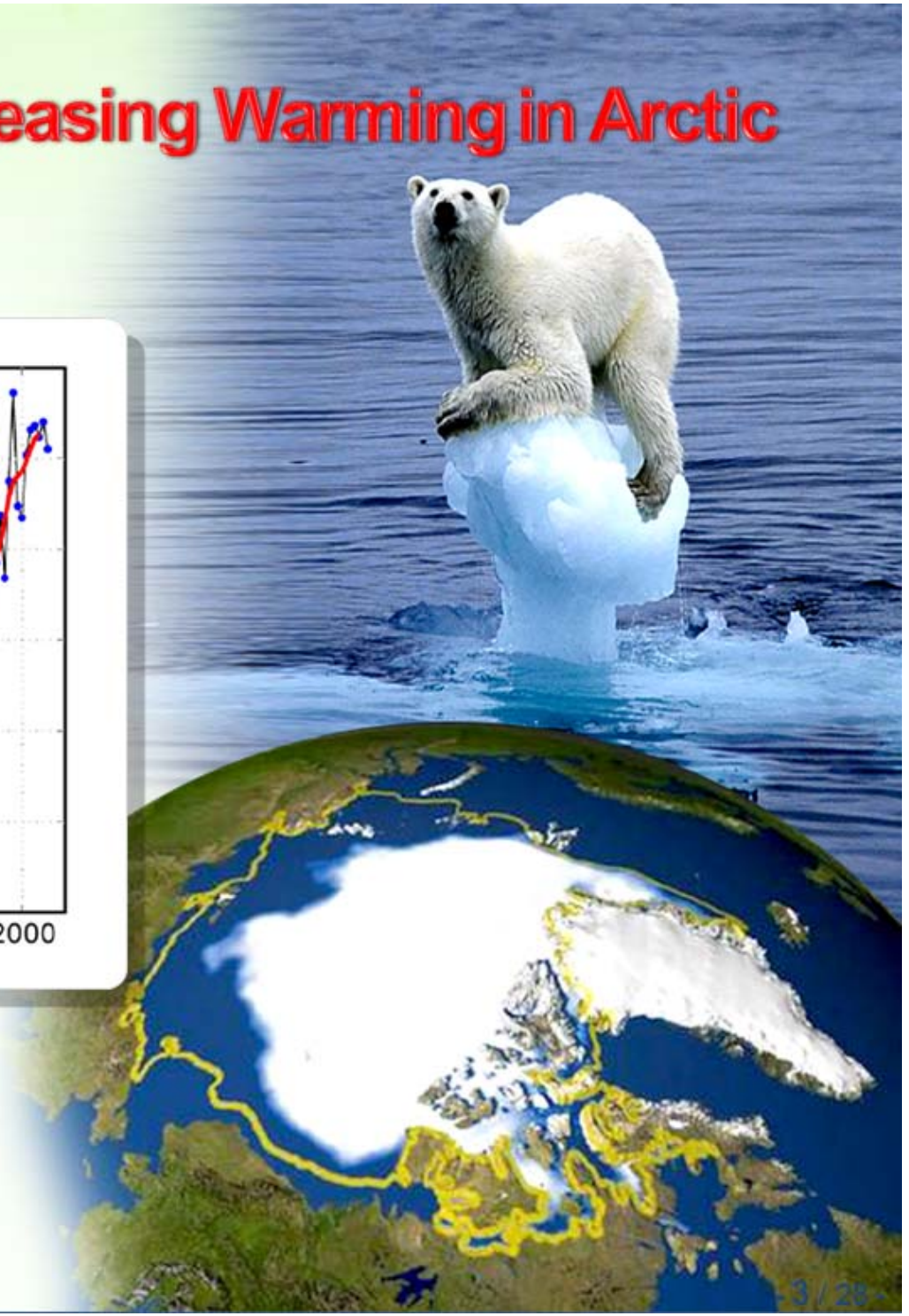
1. Background

Global Warming - A Big Dangerous Threat

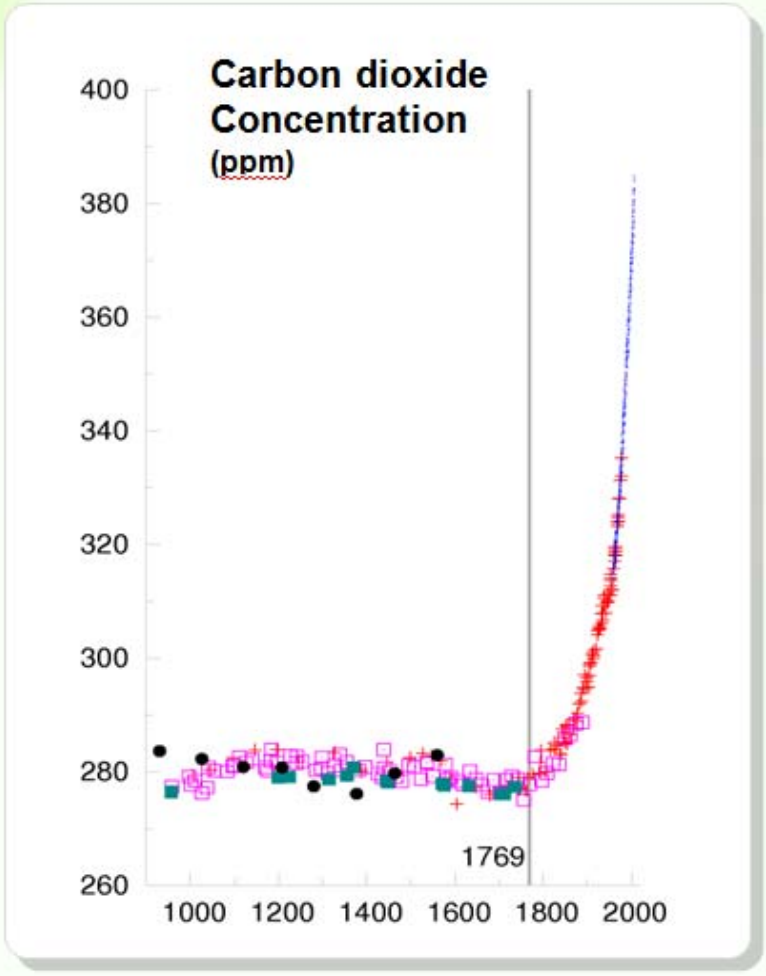
Global Temperatures Increasing Warming in Arctic



(source) IEEE 2009 Panel Green Communication

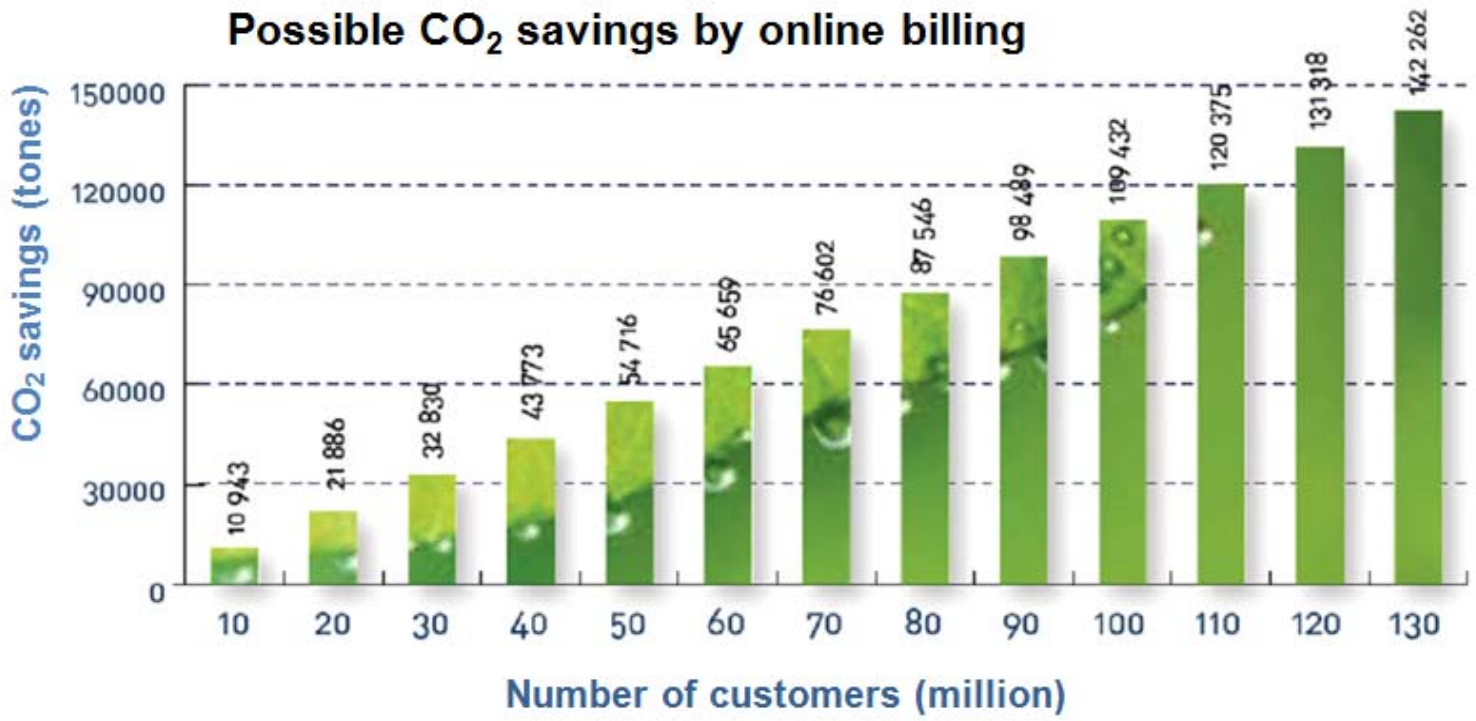


Indicator of the Human Influence on the Atmosphere during the Industrial Era



(source) http://www.phy.cam.ac.kr Prof. David Mackay, Cambridge University

Green Communications – Telecommunication Value in Promoting Environmental Improvement



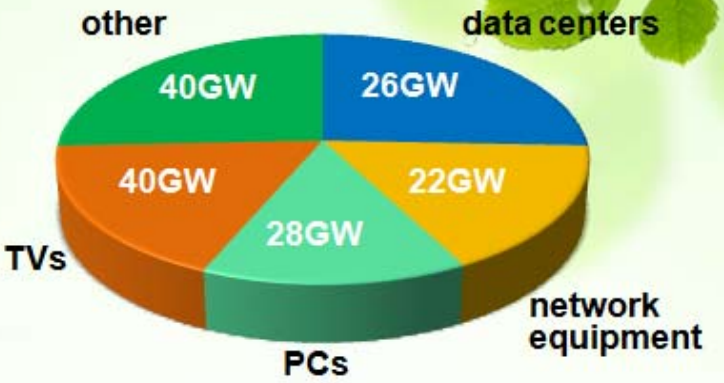
Telecommunication Applications can have a direct, tangible impact on lowing greenhouse gas emissions, power consumption, and achieving efficient recycling of equipment waste.

(source) Saving the Climate @ the speed of light, WWF

2007 world-wide ICT carbon footprint:

2% = 830 m tones CO_2

Expected to grow to **4%** by 2020



Total Emissions: 1.43 billion tones CO_2 equivalent

PCs, peripherals and printers 57%

820m tons CO_2

Telecoms infrastructure and devices 25%

360m tons CO_2

Data centres 18%

260m tons CO_2

(source) GeSI 2020 Report "ITU and Climate Change", April 2008

2. Issues

Energy issues for IT Industry

Terminal: Power saving

- Mobile terminal: battery issue
- TV, PC: less power consumption, wireless power transfer issue

Network: focused on throughput, High OPEX for operators

- Fixed Access / Core: Optical/DSL Cable Modem Tech.
- Wireless Access: Antenna, Network Topology, Power Management
- Switch and Router
- Content Dissemination

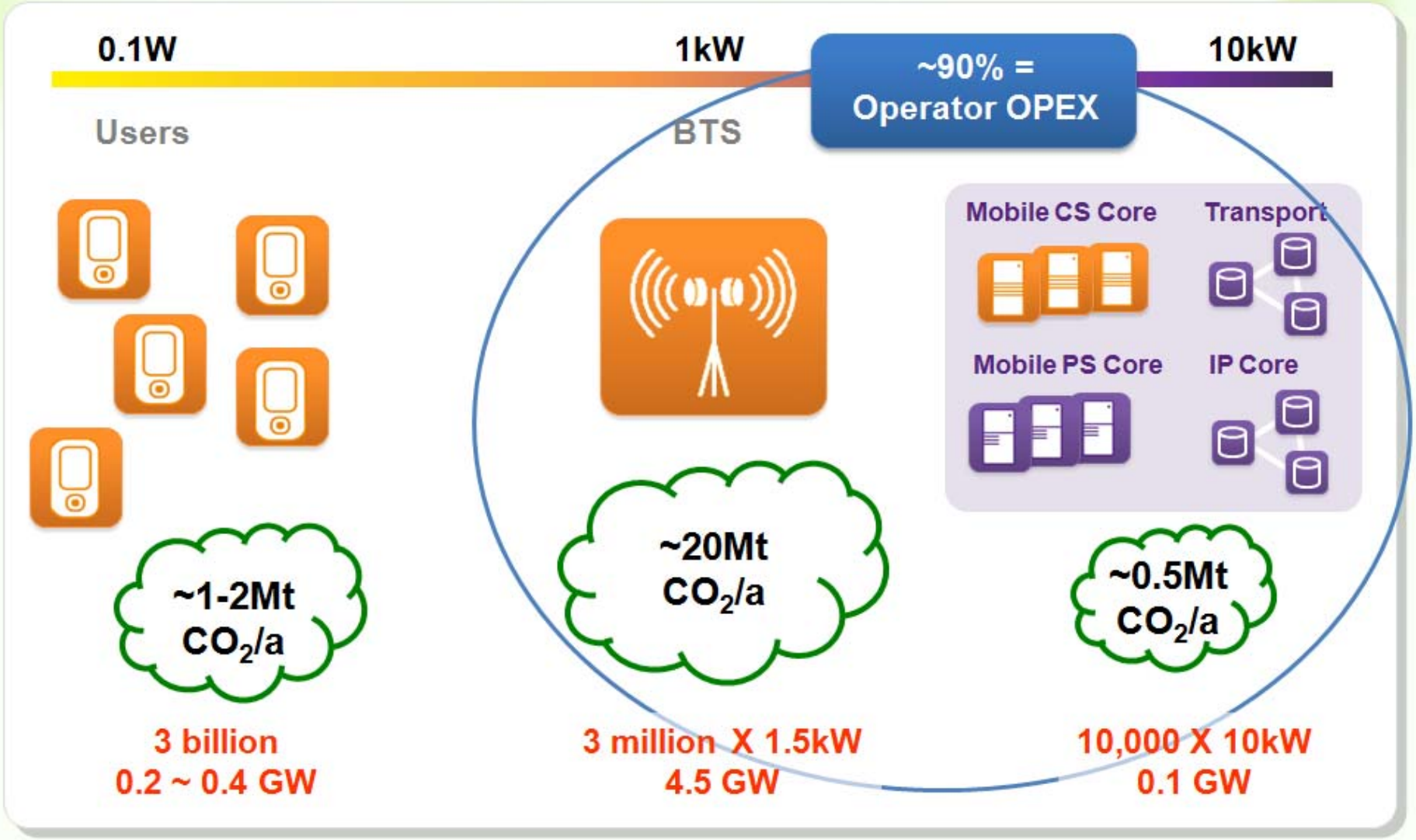
Server: Cooling & New Architecture

ICT Use Phase: Typical Figures

Equipment type	Power consumption during active mode (average load)
desktop PC with LCD display	100W
desktop PC with LCD display	150W
laptop PC	30W
CRT TV	150W (0.34W per square inch)
LCD TV	190W (0.29W per square inch)
Plasma TV	330W (0.34W per square inch)
Gaming console	220W
Volume server	700W
Mid-range server	1000W
Core routers and switches	5W per Gbit/s throughput
Access routers and switches	>10W per Gbit/s
Home gateway	7W
GSM Base Station	700W
WiMAX Base Station	400W

(source: IBBT)

Power Consumption of Cellular Network



(source) NSN

3. Green Activities

Consortium	Overview	Goal
MOBILE VCE	• Research Consortium of mobile/personal communications areas led by Industry • 11 partners including Vodafone, Nortel, Alcatel-Lucent, NEC, Nokia Siemens Networks	Network energy efficiency by a factor of 100 from current levels
OPERA-Net Power efficient Wireless	• A program to improve energy efficiency of network • 10 partners including Alcatel-Lucent, France Telecom, Freescale , IMEC, Nokia Siemens Networks, Thomson	Power efficiency improvement of radio access network (25~50%)
earth Energy Aware Radio and neTwork tecHnologies	• FP7 Program for Energy Saving in Mobile communication systems • 15 partners including Alcatel-Lucent, Ericsson, DOCOMO, CEA-LETI, IMEC	Over 50% energy saving in 4G wireless communication network
GreenTouch	• By 2015, its goal is to deliver the architecture, specification and roadmap • 31 partners including Bell Lab, AT&T, Orange, Huawei, SAIT	Network energy efficiency by a factor of 1000 from current levels

Green Touch Consortium

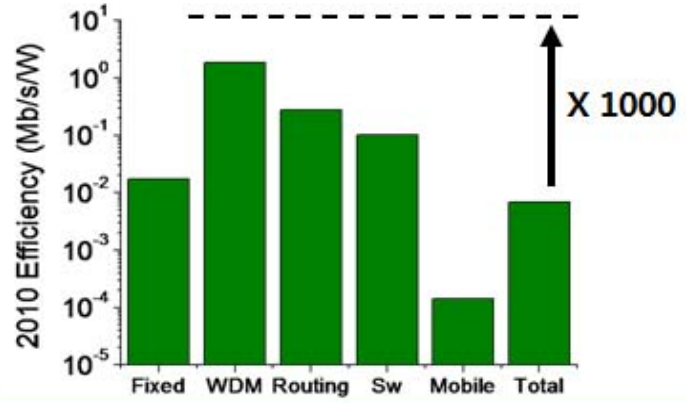
Green Touch Mission

- by 2015, its goal is to deliver the architecture, specifications and roadmap – demonstrate key components – needed to increase network energy efficiency by a factor of 1000 from current levels.

Organization

- Led by Bell Lab & 31 partners including Alcatel-Lucent, AT&T, Huawei, SAIT, Columbia University, IMEC so on
- 4 Working Groups: Wireless, Fixed, Transmission, Switching & Routing

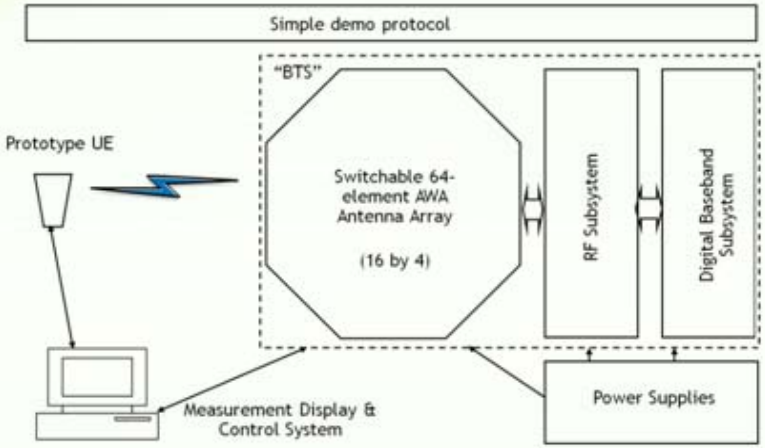
GTC goal based on 2010 network architecture



Use Architecture Models & Target to track Progress

Massive MIMO Project

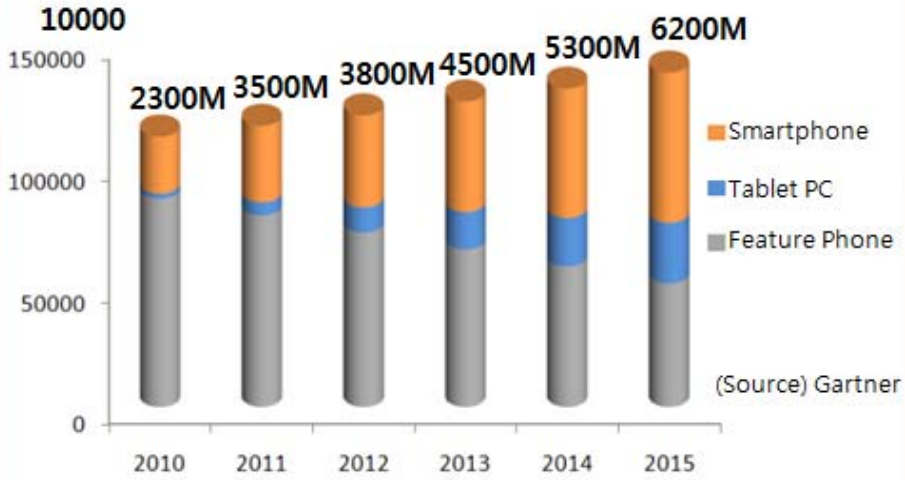
Large Excess of Base Station Antennas over Terminals
Yields Energy Efficiency + Reliable High Throughput



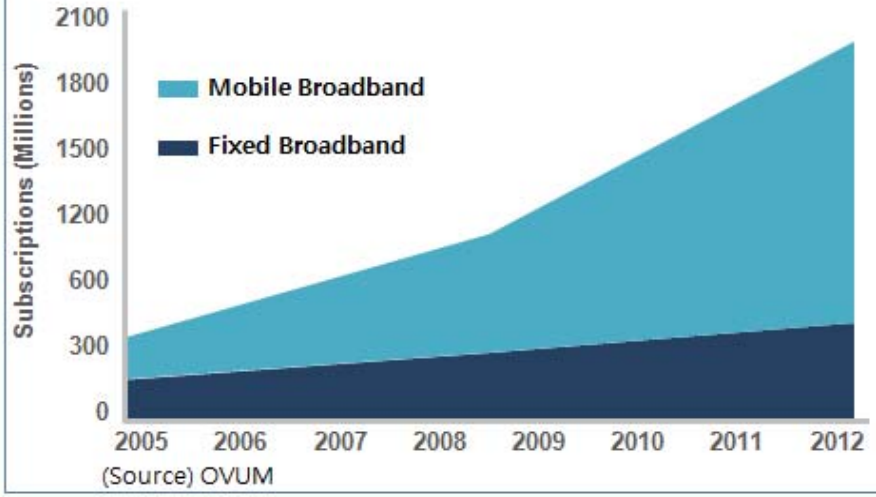
- **M~400 base station antennas serve K~40 terminals via multi-user MIMO**
  - Doubling M doubles the power that the terminal receive (given perfect CSI)
- **Milestone for Demo**
  - Phase I Demo in London (Feb. 2011) – 16 antennas with downlink
  - Phase II Demo (2012) – 64 antennas with up/downlink
  - Long-term – 400 antennas with beamforming and MIMO

Mobile Service in Internet

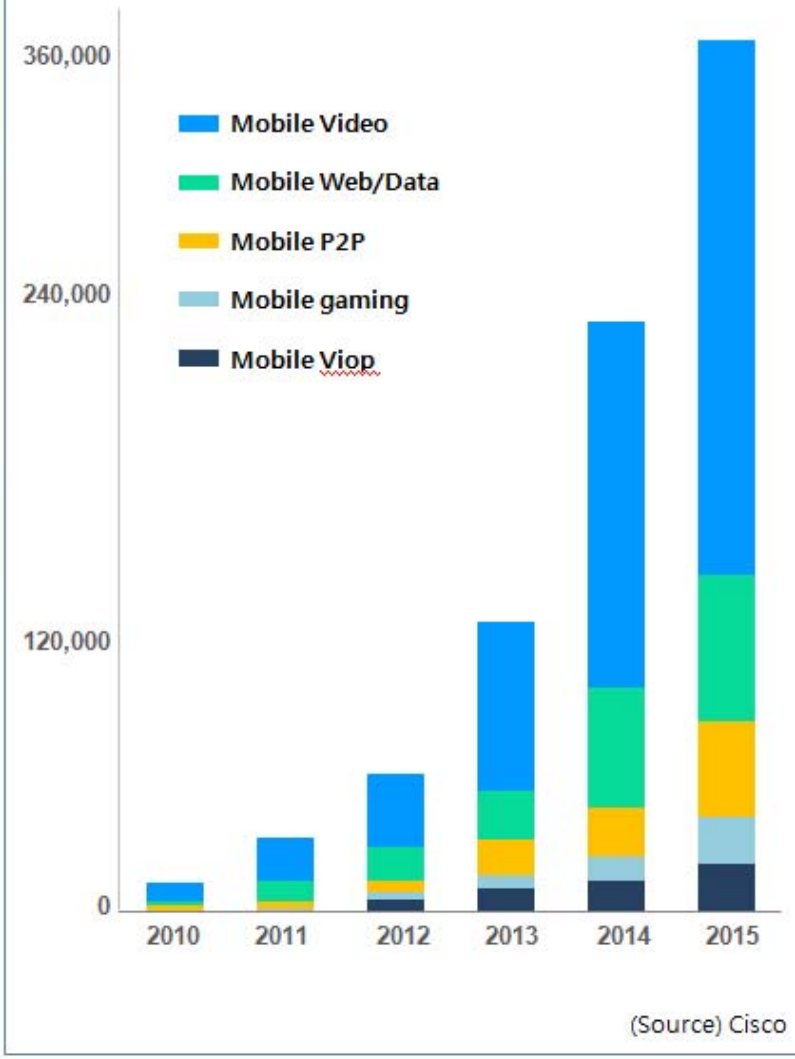
Worldwide Mobile Device Subscription Forecast



Mobile Broadband vs. Fixed Broadband

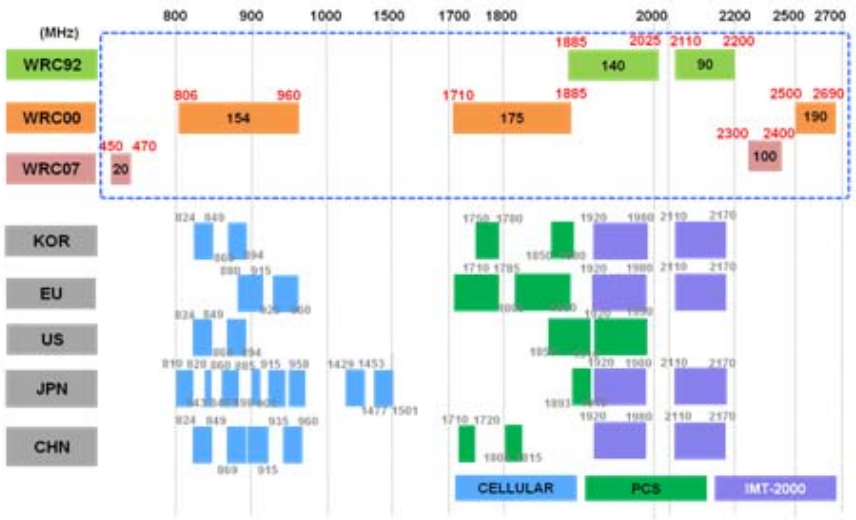


Worldwide Mobile Data Traffic Forecast

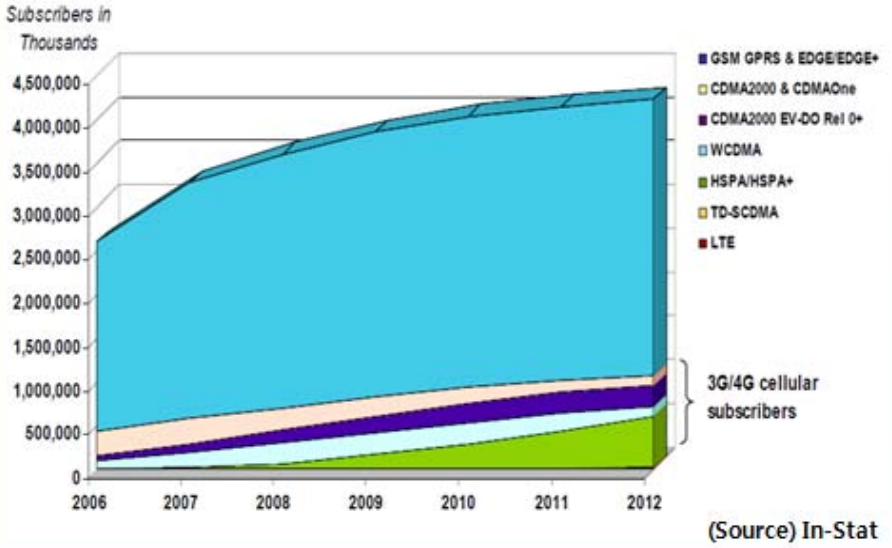


Perspect for Base station in Future Mobile Communication

Frequency Band



Worldwide Mobile Subscriber Forecast



(Source) In-Stat

Future BS increase from 3 M to 30M or 300 M

- **Femtocell, Wireless BS increase (Mesh or Ad Hoc)**

- **Precise Location Selection by Cell Planning → Coverage Overlap**
- **Concentration of Urban Population → Wide coverage for rural area**

4. Green Technologies - Advanced Antenna Technology

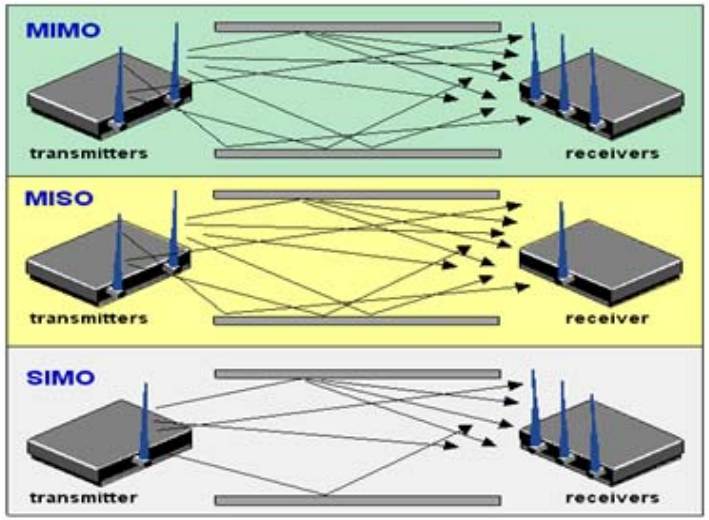
Overview

- Performance Improvement and energy saving thru multiple antenna array
- Massive (Large scale) MIMO : BS with over 100 multiple antennas

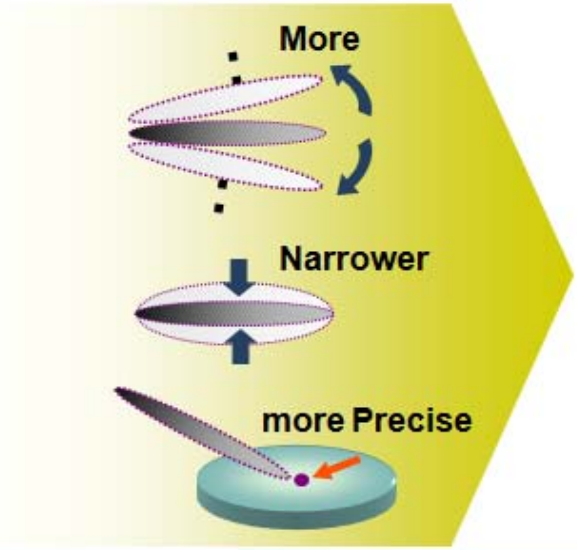
Issues

- Only use at TDD (Time Division Duplexing) mode
- Feasibility for Wide Area Implementation

MIMO Technology



Beamforming Technology

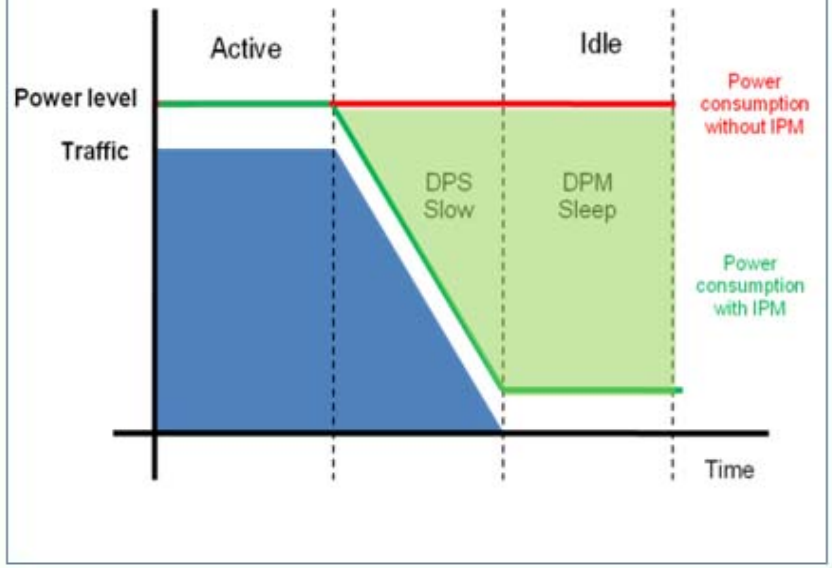


Intelligent Power Management

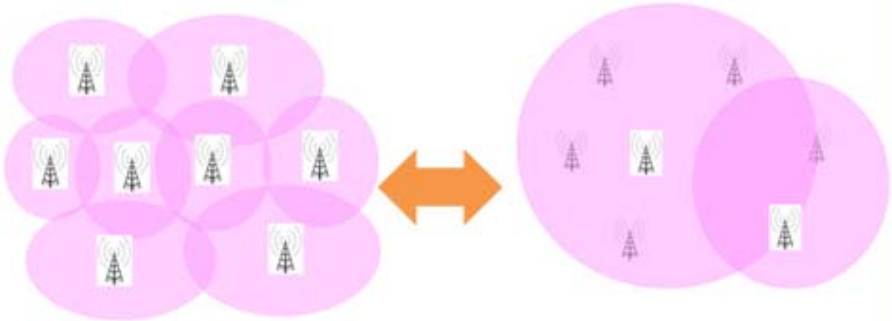
Overview

- Energy Saving thru adaptive BS operation
- Dynamic Power Management (DPM): Shut down when no traffic
- Dynamic Performance Scaling (DPS): Slow down when low traffic

IPM Power Saving



IPM for Green BS



Hybrid Small Cell Management

Overview

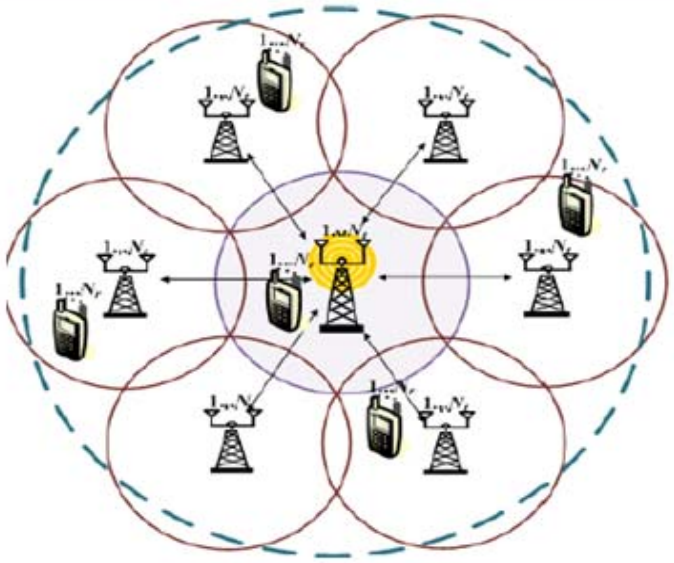
- Energy Efficiency maximization thru collaboration between cells

Issues

- No collaboration method between Macro/small & small/small
- Handoff problem due to Mobility for terminal

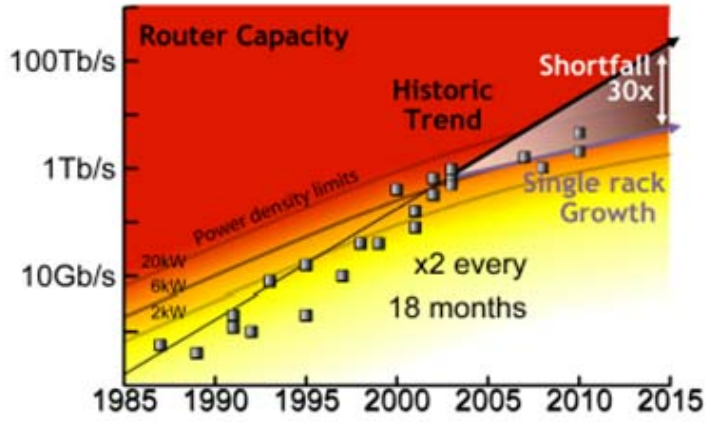
Huawei DBS solution Concept

Energy efficient distributed system

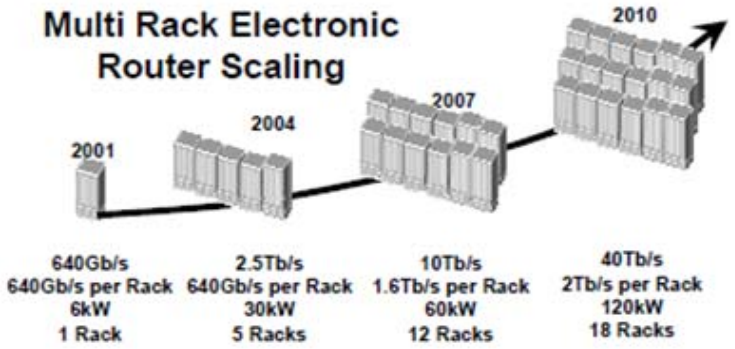


Internet & Router

Annual Router Capacity Growth

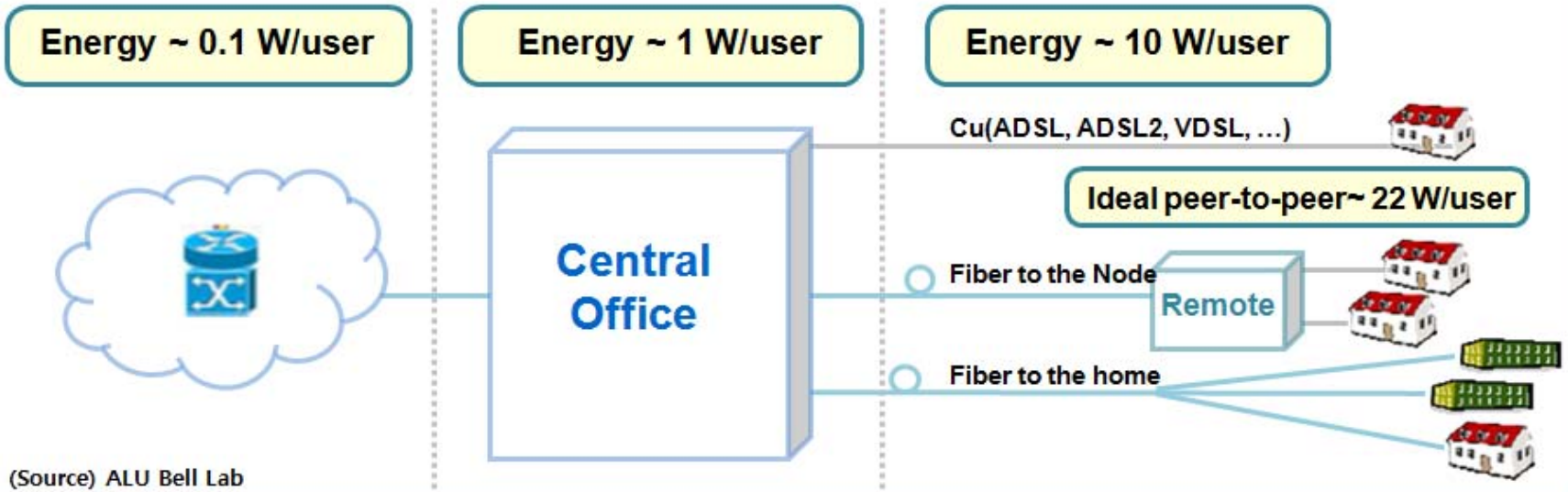


Router Capacity & Power Consumption Growth



(Source) Router Energy and Scalability, David Nielson, Alcatel-Lucent

Relative Power Consumption Rate in Core, Metro & Access network

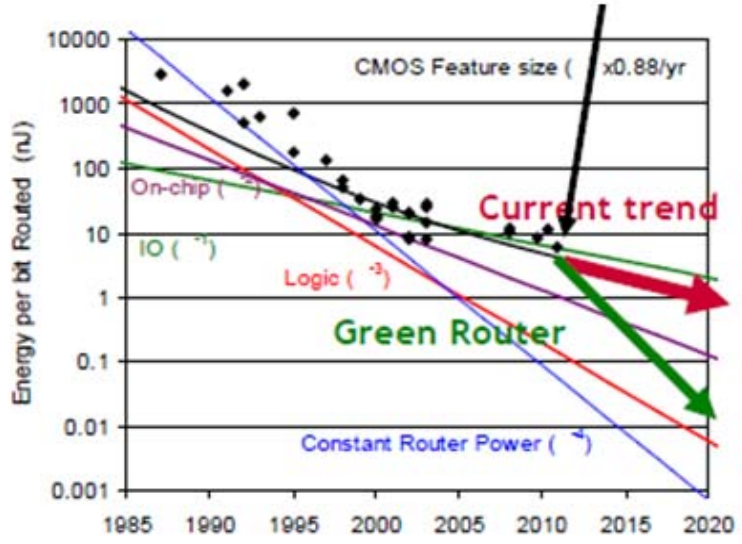


(Source) ALU Bell Lab

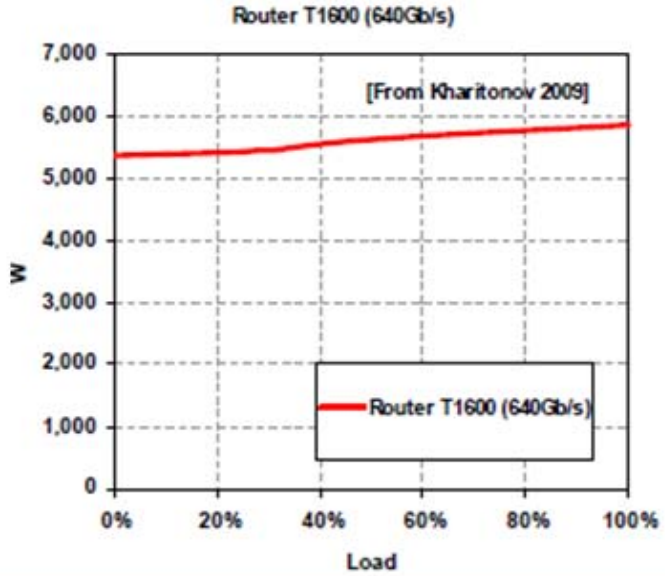
Router

- Router energy efficiency improvement lags behind data traffic growth.
  - Energy per bit for routing decreases 10% per year while traffic increases 40% per year.
- Router consumes power irrespective of actual traffic processing.
  - Energy cost is a function of capacity, not throughput.

Router energy efficiency trend



Energy Consumption vs. Offered Load



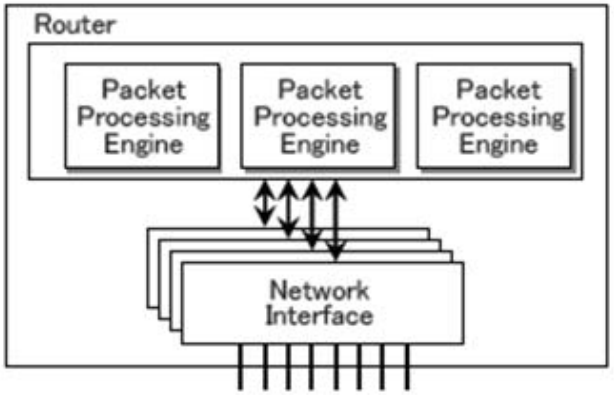
[Source GreenTouch Router Energy and Scalability, David Nielson, Alcatel-Lucent

[Source] Energy Use and Savings in Communications, Bruce Nordman, Lawrence Berkeley National Lab

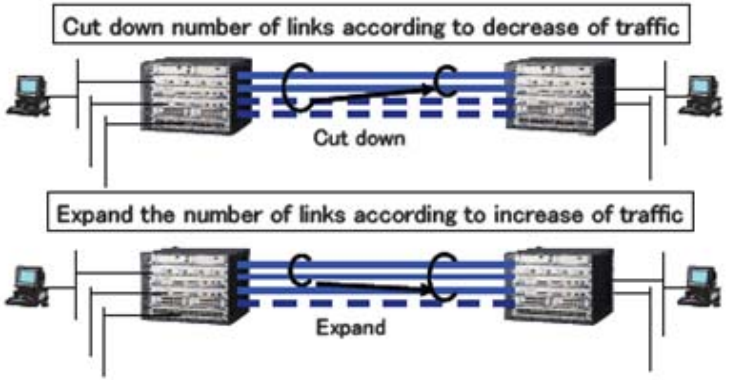
Router

- **Rate adaptive router**
  - Router consumes power according to processed traffic.
  - Shut down when no traffic or slow down when low traffic.
- **Scalable central packet processing**
  - Multiple packet processing engines powered on according to traffic rate. The larger the traffic, the more packet processing engines.
- **Power saving Link Aggregation**
  - dynamically control the number of links under operation for power saving.
  - reduce the number of active links belonging to the Link Aggregation group when traffic is small

Scalable central architecture



Performance control by link aggregation



(source) Power Efficient Approach and Performance Control for Routers, Masaki Yamada et all, GreenComm'09

Content Centric Network

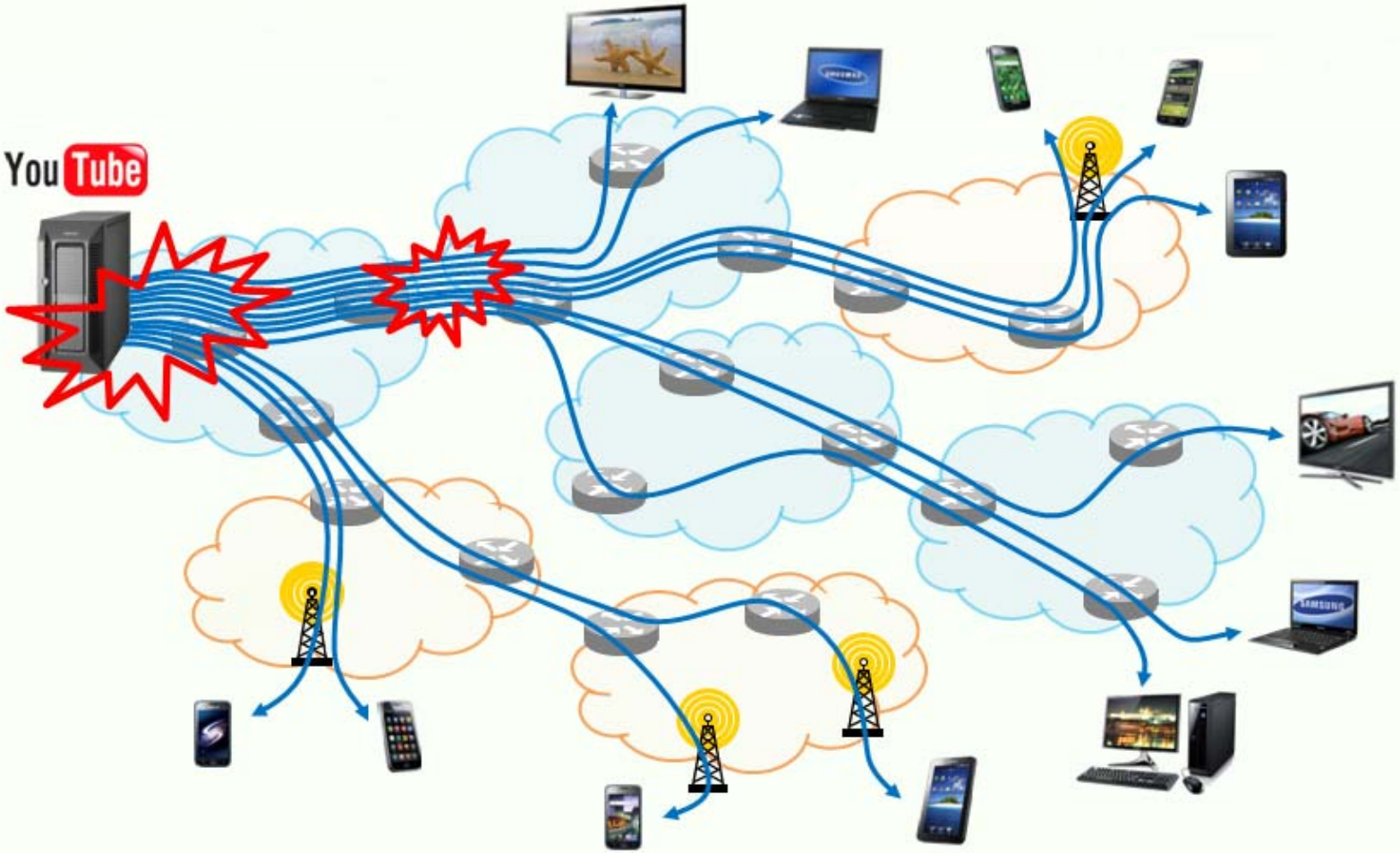
A routing scheme based on contents instead IP address

Concept & Challenges

- Name based Routing
  - Content name becomes network address for direct routing without resolution system
- Naming
- Flat & Hierarchical
  - TRIAD: hierarchical URL, DONA: flat, CCN: hierarchical, agnostic
- Scalability & Security

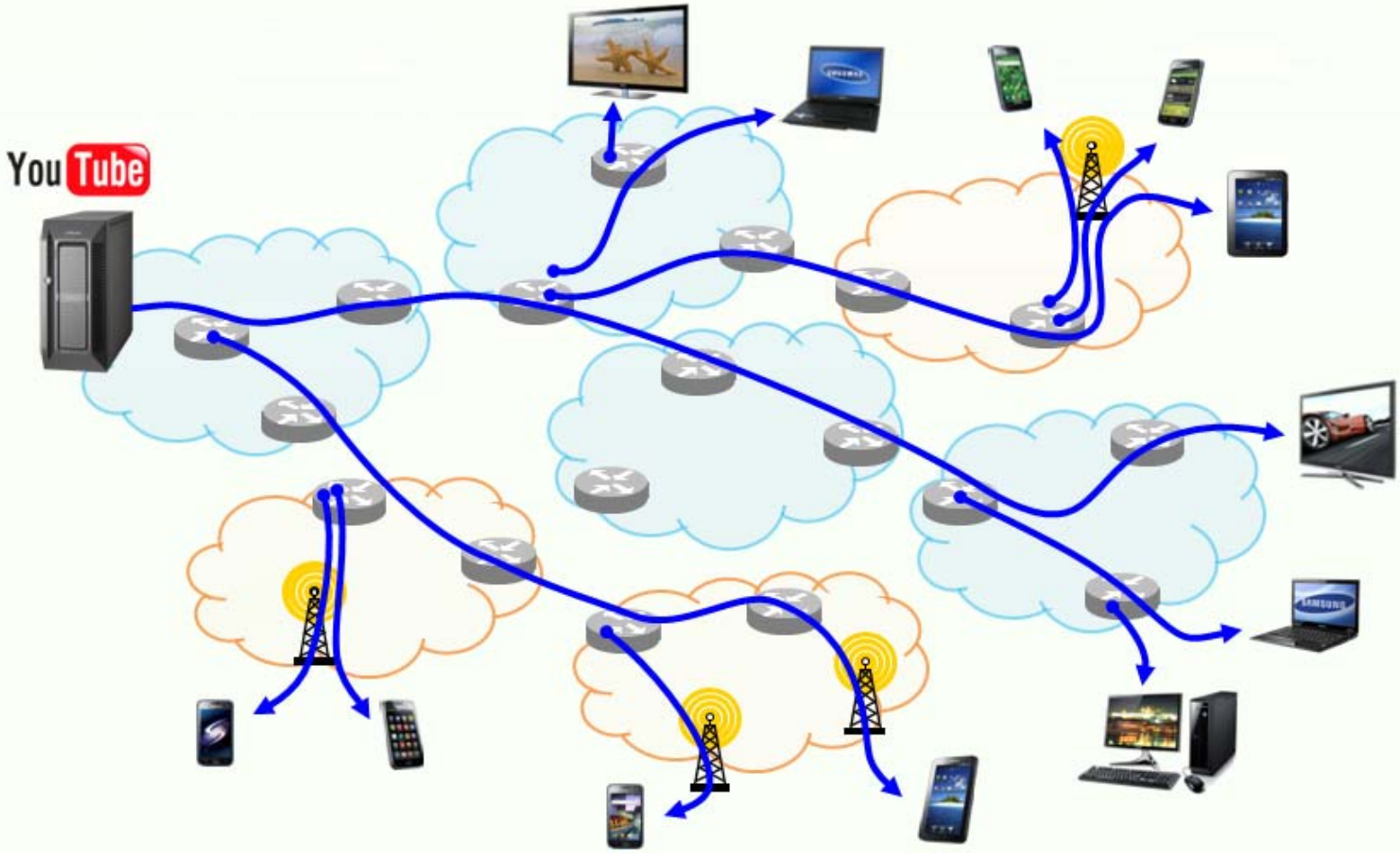
Data Flow in Current Internet

- End host-to-end host communication
- Client/Server-based networking
- No multicasting
- Less energy efficient content distribution



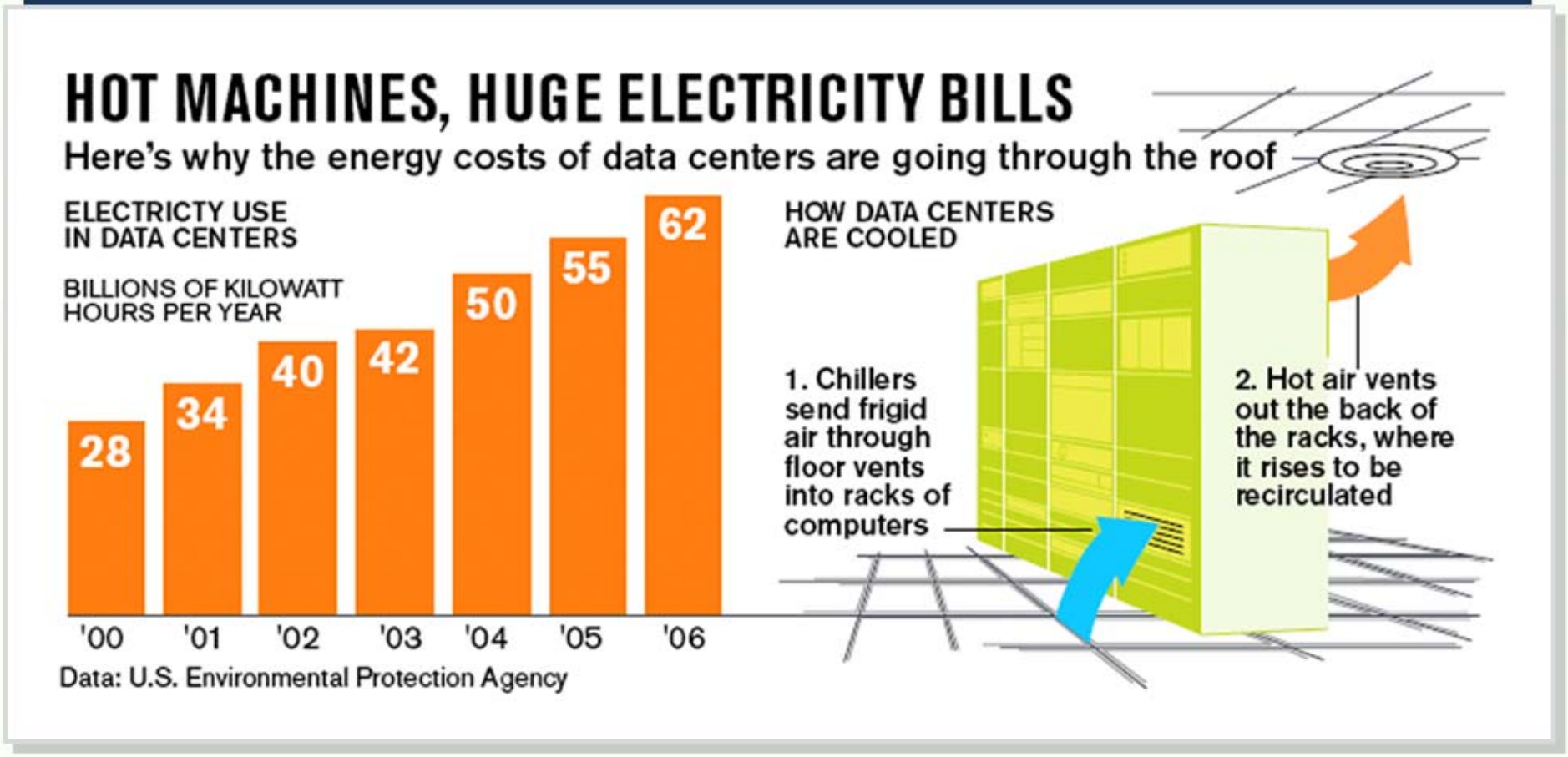
Data Flow in CCN

- End host-to-content communication
- Location-independent content-oriented networking
- Multicasting effects
- More energy efficient content distribution



Server Issue

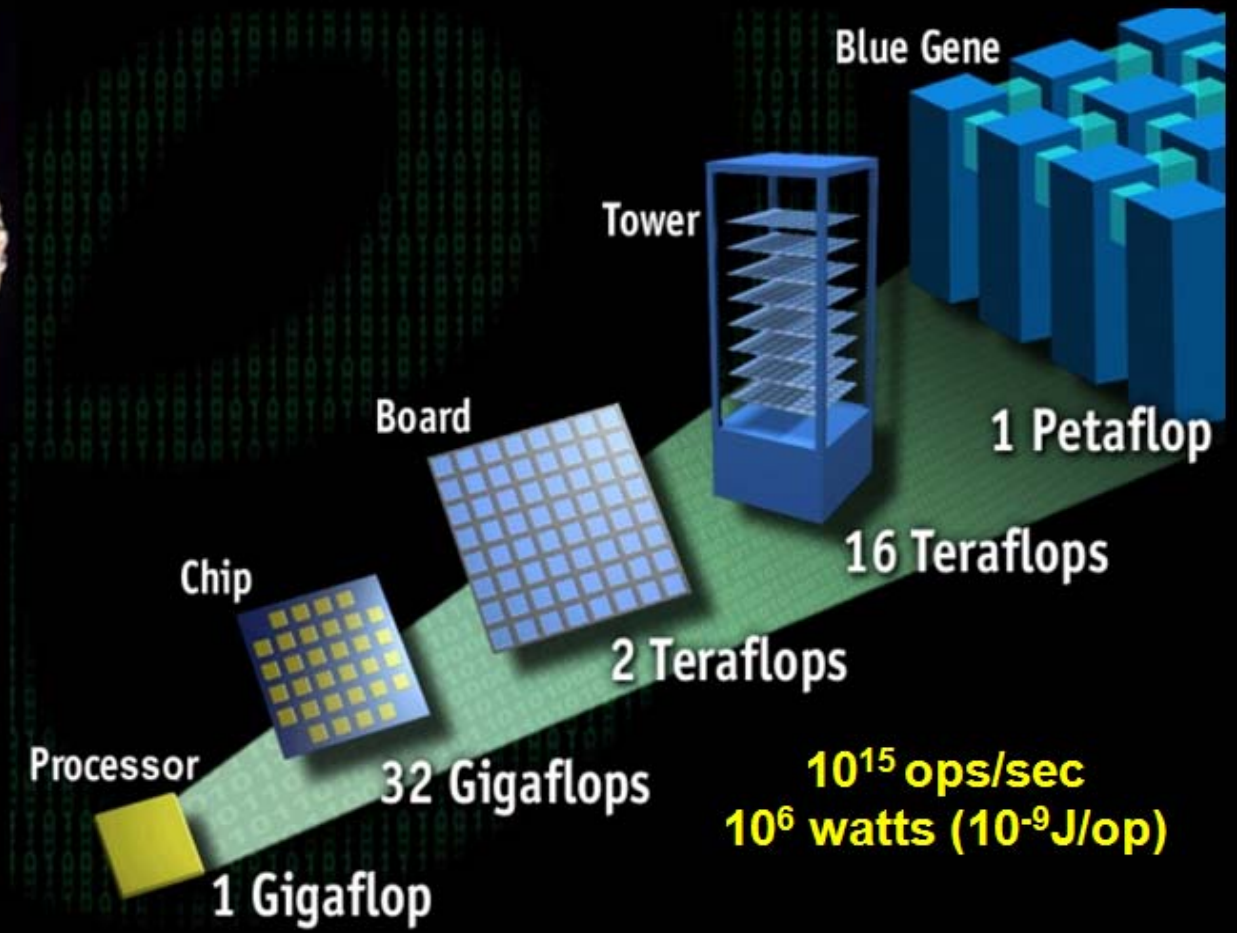
Energy Cost and Power Consumption Increasing With Telecommunication



(source) US Environmental Protection Agency

Brain VS Computer

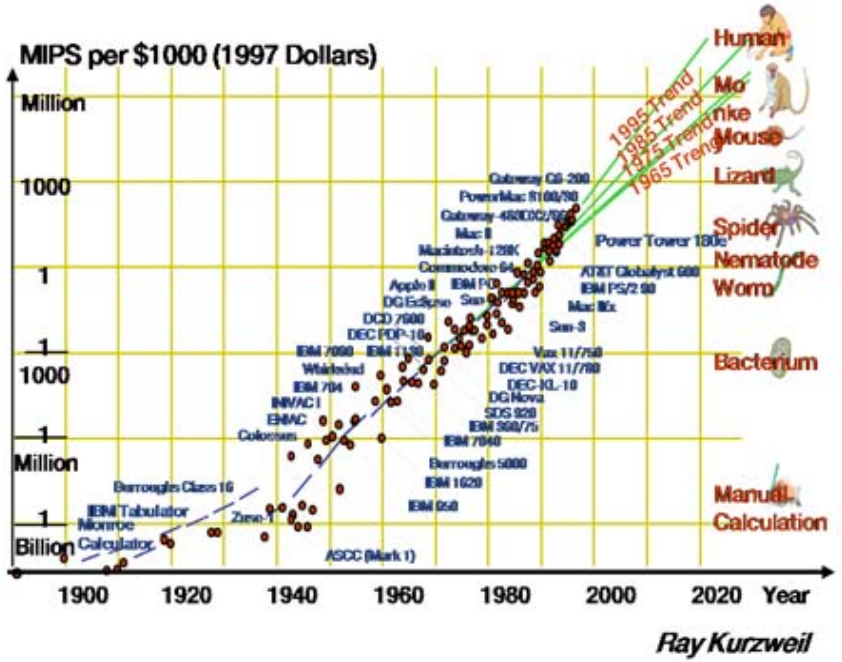
10^{16} synaptic events/sec
20 watts (10^{-15}J/op)



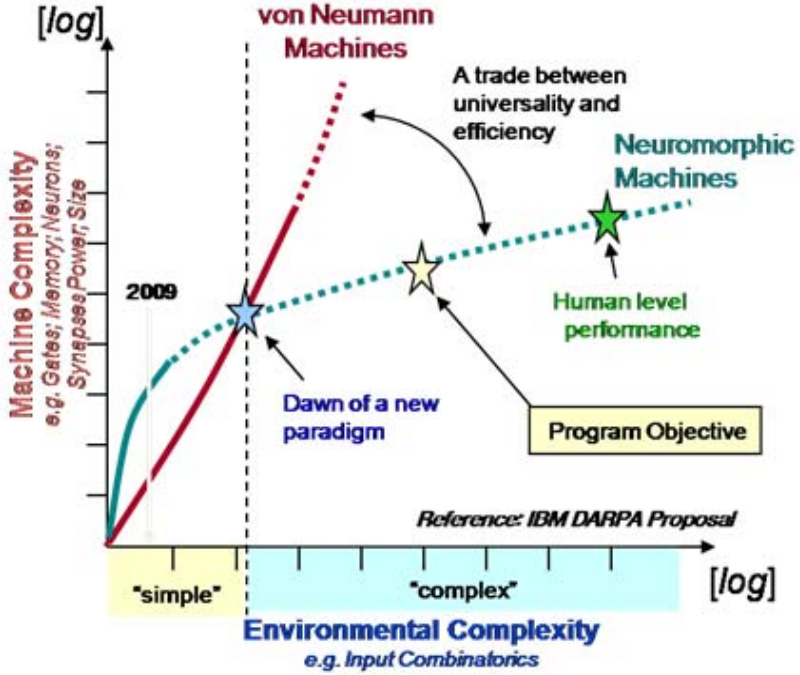
Evolution of Computer

- 2025, A $1,000 computer may have human being's intelligence
- Von Neunmann architecture is not enough for future application
  - Recognition and reaction of natural voice, vision, feeling, tasting
  - Resolution for undefined situation

Evolution of MIPS / $1000

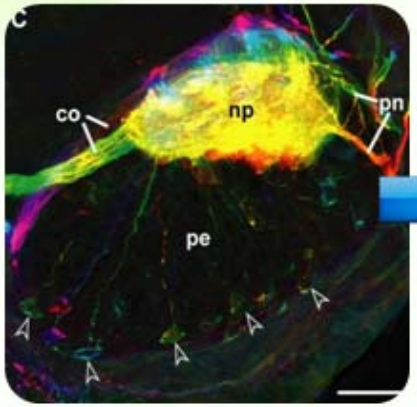


Comparison of complexity

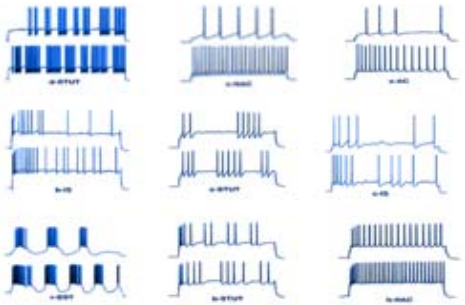


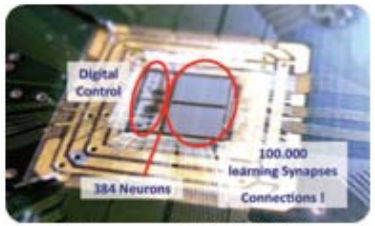
Neuromorphic Technology

- A silicon neuron working like a real neuron



1. Temporal spiking neuron modeling

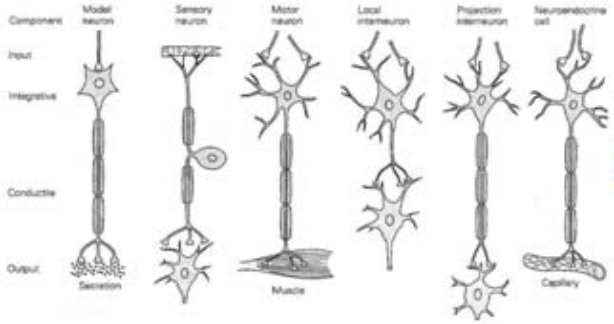


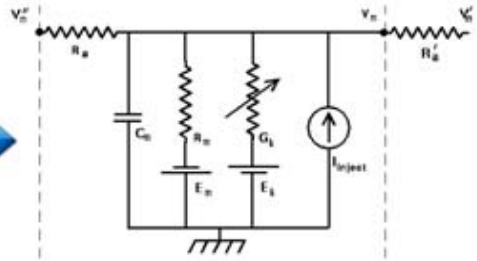


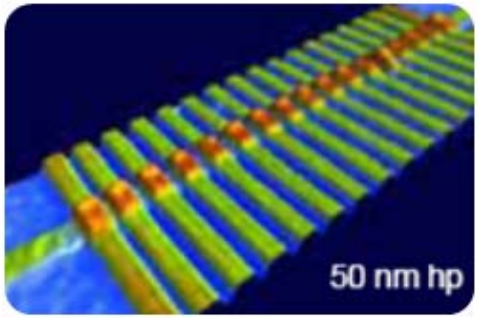
Neuro chip ('09)
(384 neurons, 10^5 synapses)

BrainScaleS ('14)
(10^6 neurons, 10^8 synapses)

2. Communication based on neuronal circuits





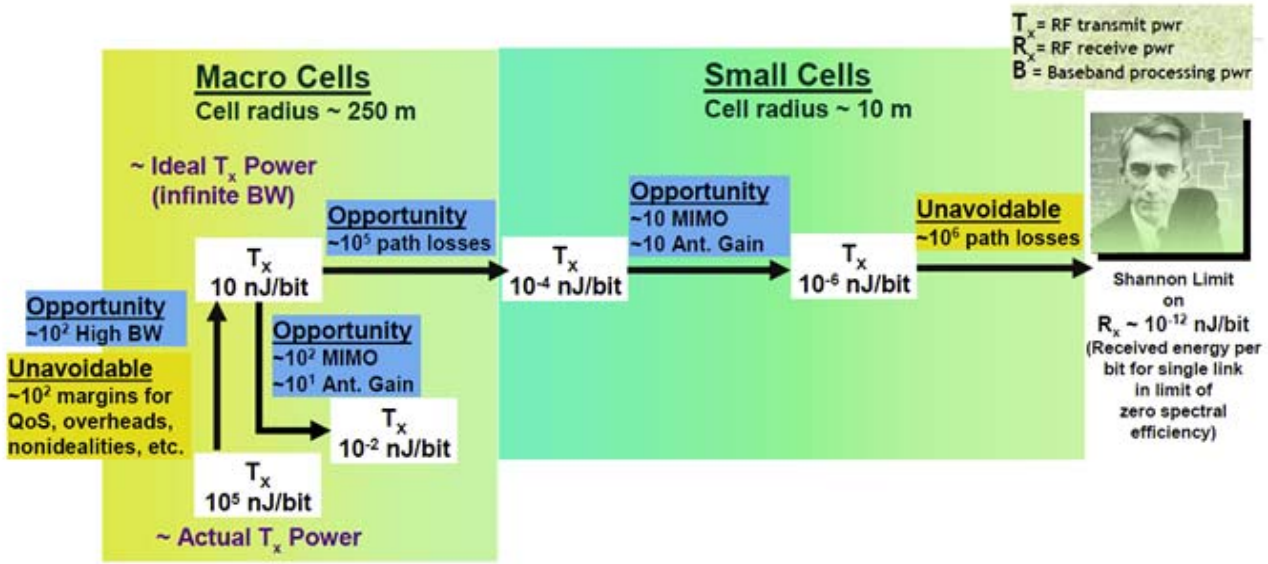


Memristor ('08)

5. Conclusion

Content-Centric Distribution

10^{16} synaptic events/sec
20 watts (10^{-15}J/op)



Thank you