From Wireless to Ubiquitous Communication and the Path Ahead

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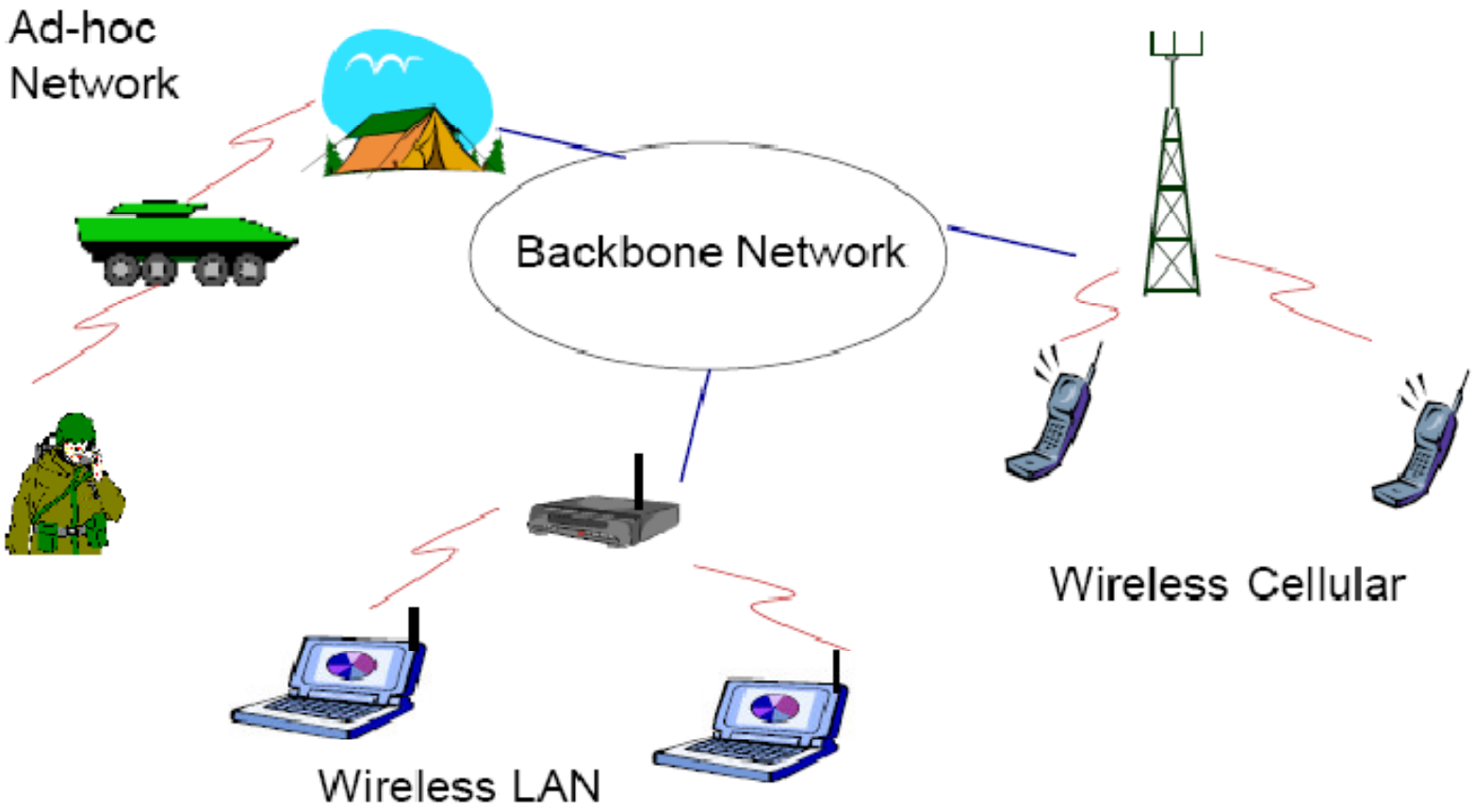
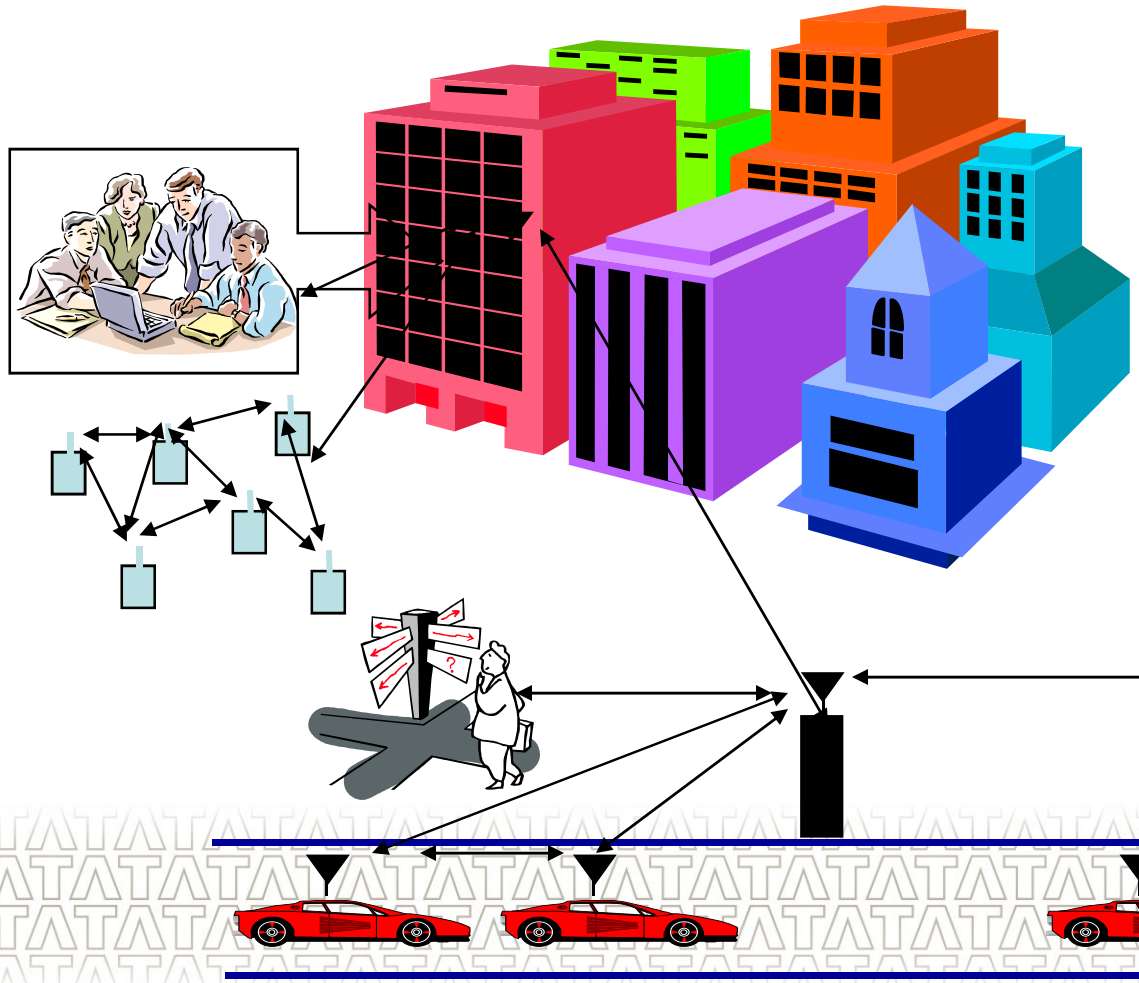
Talk Outline

1. 4G Wireless Communication Issues, Challenges Trends and Architecture
2. Wireless Channel Dynamics
3. Advanced Multiple Access Scheme : OFDMA
4. Multi-user Diversity and Spectral Efficiency
5. Link adaptation
6. Cross-layer Optimization: Scheduling and Resource Allocation
7. QoS
8. Game Theory in Wireless Network Optimization
9. SDR
10. NEMO
11. Ubiquitous Computing and Communication
12. Home Gateway

Wireless Networks



Future Wireless Networks



- Wireless Internet access
- Nth generation Cellular
- Wireless Ad Hoc Networks
- Sensor Networks
- Wireless Entertainment
- Smart Homes/Spaces
- Automated Highways
- All this and more…

Future of Wireless Communications

- Ubiquitous Communication Among People and Devices
- Wireless Internet access
- N^{th} generation Cellular
- Wireless Ad Hoc Networks
- Sensor Networks
- Wireless Entertainment
- Smart Homes/Spaces
- Automated Highways

Vision of Future Wireless Communications

- Anytime, anywhere computing
- Enhanced communications
- Always-on : network access for users on the move
- Support of Heterogeneity
- Minimum user interface

We Want More

Apart from Voice Traffic The applications require high data rate and variable QoS

- *e-mail*
- *multimedia messaging*
- *Internet browsing*
- *video conferencing*
- *audio and video streaming*
- *e-commerce*
- *mobile TV*

Targets of LTE

- Peak data rate
  - 100 Mbps DL/ 50 Mbps UL
- Mobility
  - Optimized for 0 ~ 15 km/h.
  - 15 ~ 120 km/h supported with high performance
  - Supported up to 350 km/h or even up to 500 km/h.
- Coverage
  - Performance should be met for 5 km cells with slight degradation for 30 km cells.
- Spectrum flexibility
  - 1.25 ~ 20 MHz
- 2X2 MIMO

Design Consideration of 4G

Desirable Characteristics	Restrictions	Tradeoffs
Portable devices, reasonable battery life	Power consumption, size, transmit power, link budget	Asymmetrical capacity, smart antennas, channel coding,
Multimedia applications, low latency	Bandwidth requirements Spectrum allocation	High peak data rate, flexible assignment
Internet access	Multi user operation, Spectral efficiency	Packet mode operation
Co existence with present services	Crowded spectrum, Interference potential	Low start up bandwidth, flexible frequency usage, coordinated parameters

Challenges

- Limited Resources : Capacity-limited medium
- Traffic patterns, user locations, constantly changing network conditions
- Heterogeneous traffic
- Hard QoS constraints
- Maximize number of users
- Maximize network coverage
- Minimize outage probability
- Guaranteed user satisfaction

Limiting Factors in Mobile Wireless Communications

- Noise
- SNR
- Multipath fading
- Interference
- Limited Power
- Frequency selective fading
- Doppler shift

Solution

Robust Multiplexing and Multiple Access Technique : OFDM/OFDMA

Intelligent user allocation : Dynamic Resource Allocation and Packet Scheduling

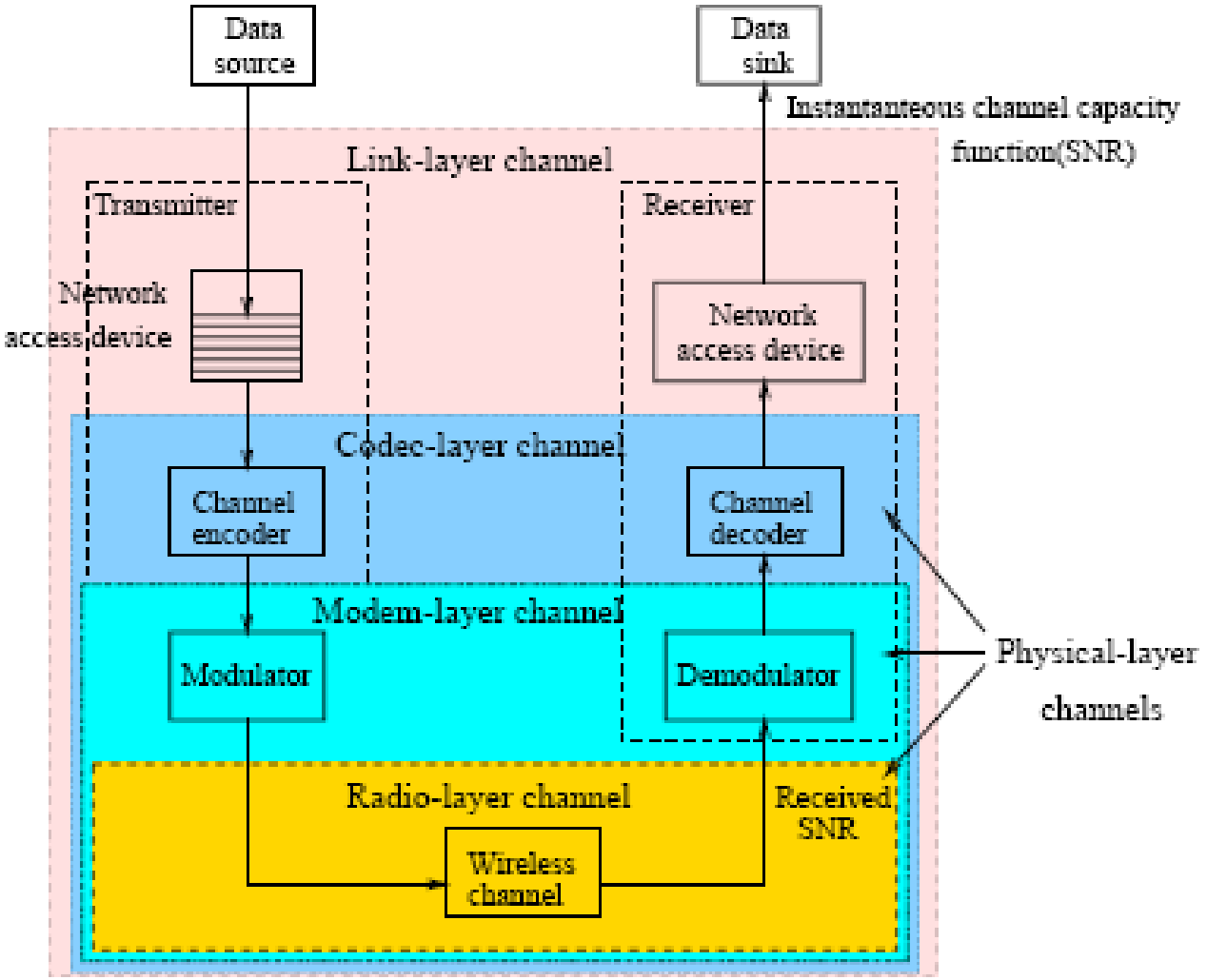
Integrated Optimization: Cross Layer Optimization

Link Adaptation : Adaptive Modulation and Coding

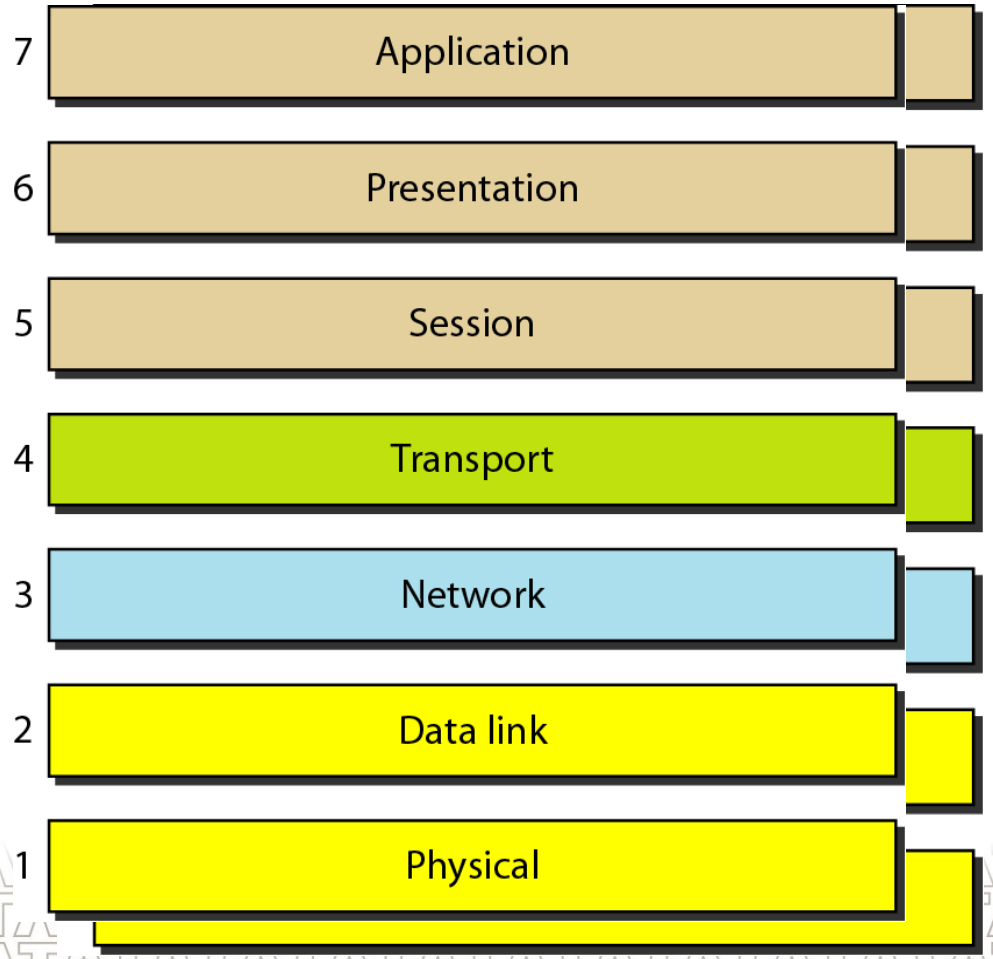
Spatial Multiplexing: MIMO

Performance Optimization: Cross-layer Design

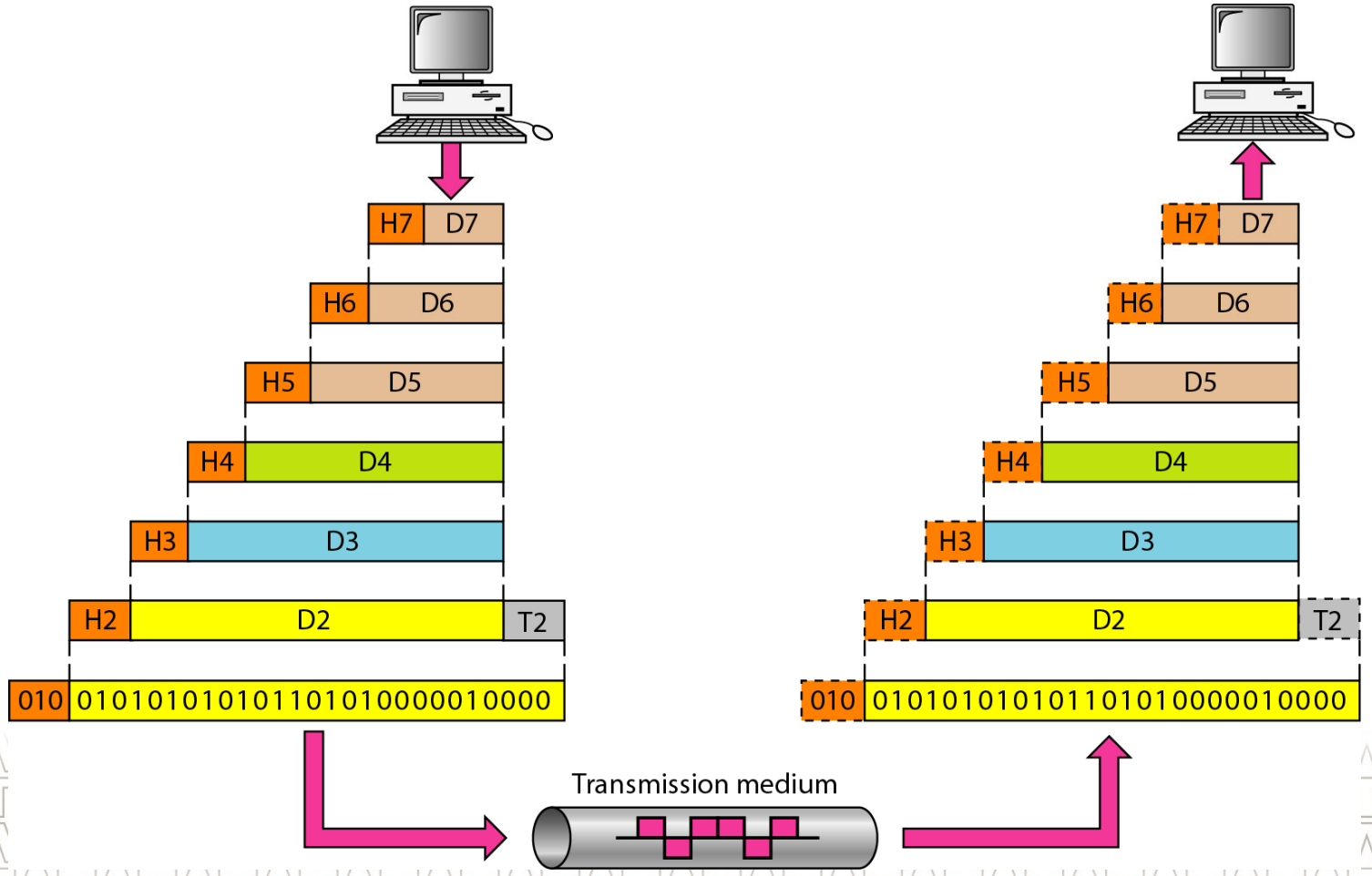
Generic Wireless Communication System Model



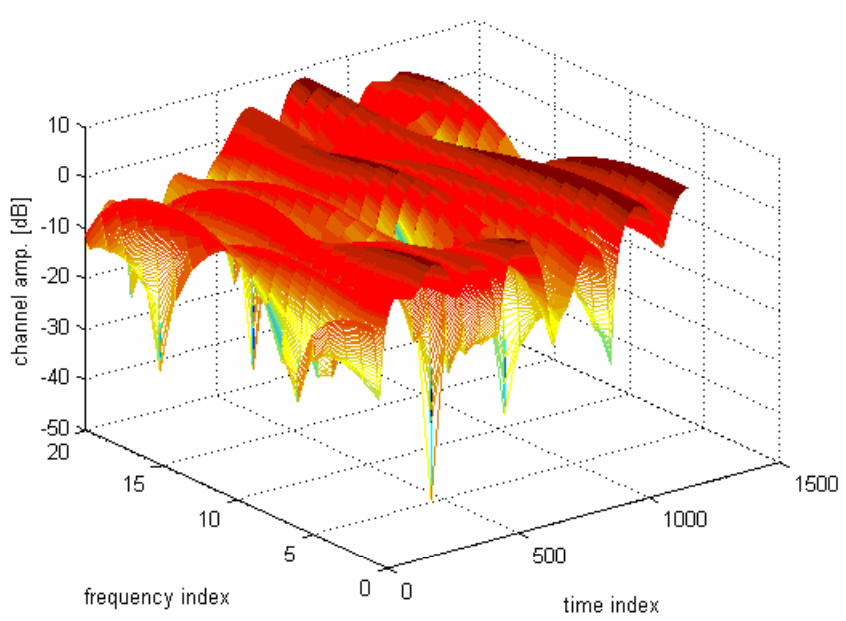
The OSI Model



OSI model: Header Based Data Networks

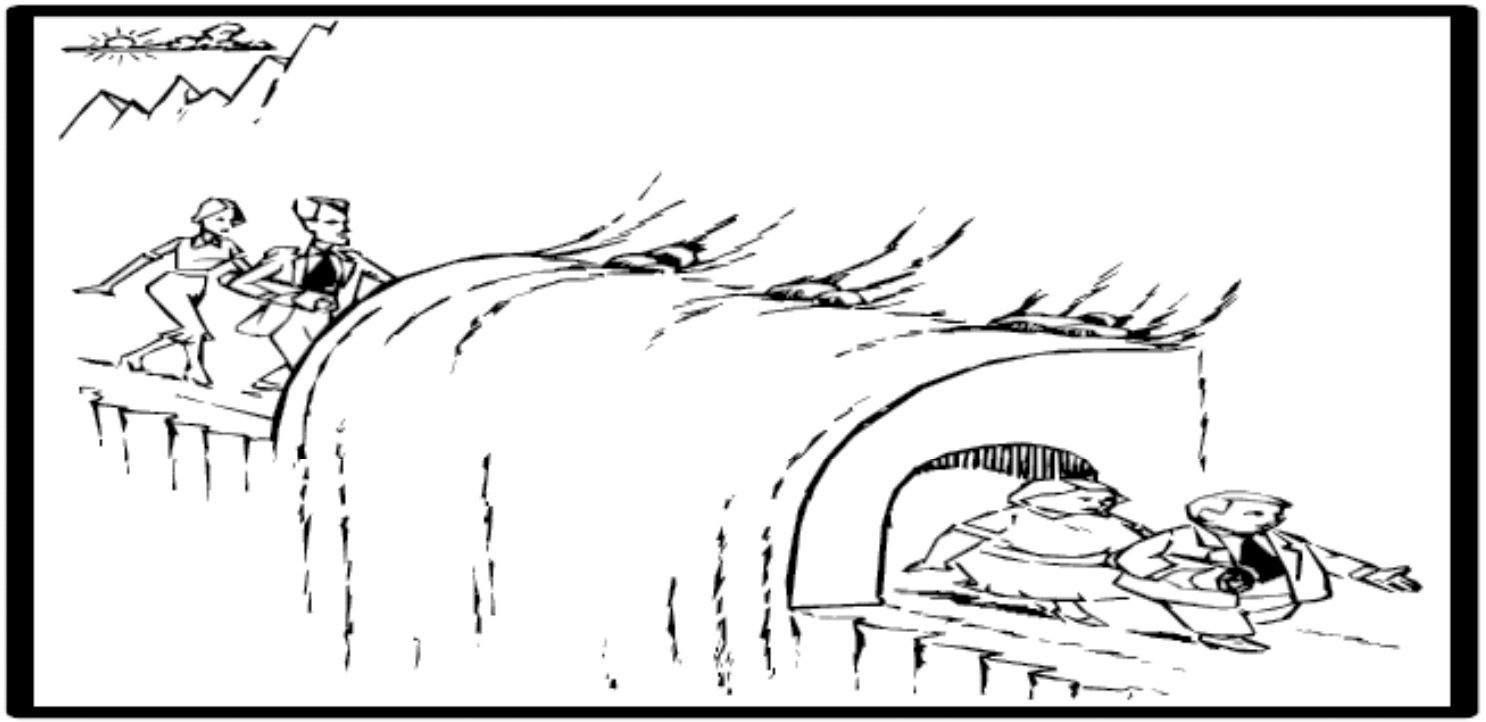


Channel Dynamics



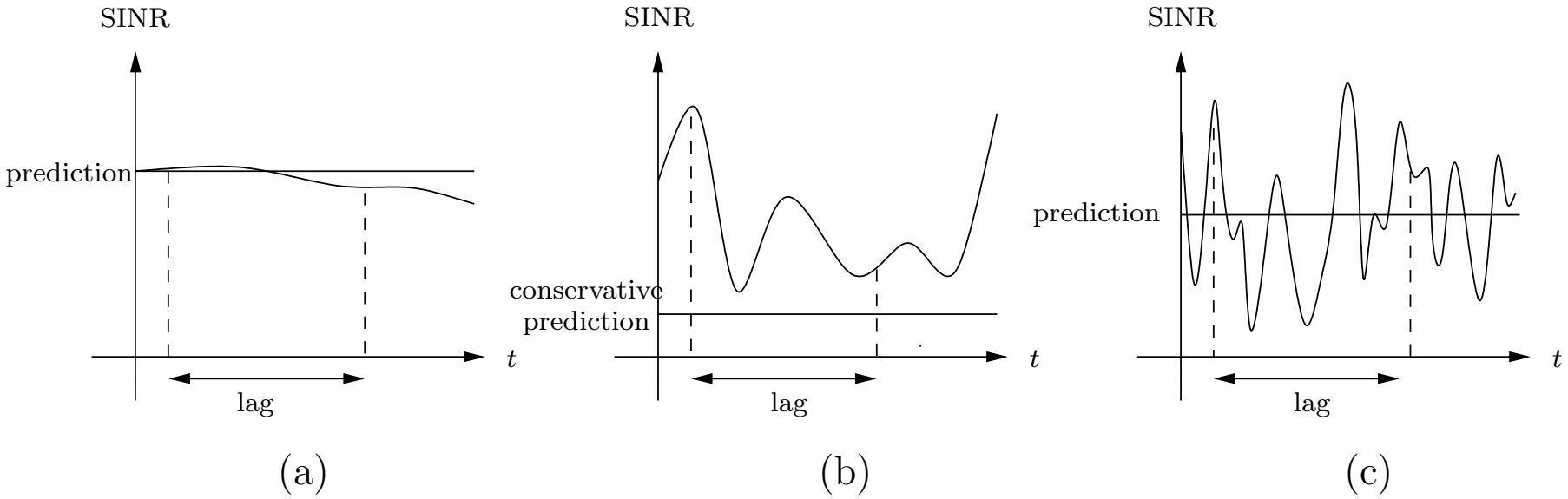
- Wireless Channel is time-varying and frequency-selective
- Multipath fading provides high peaks to exploit
- Channel capacity is achieved by such an opportunistic strategy
- Channel varies faster and has more dynamic range in mobile environments
- More appropriate for data with soft latency requirements

Attenuation, Dispersion Effects: ISI



Inter-symbol interference (ISI)

Mobility vs SNR Dynamic Range



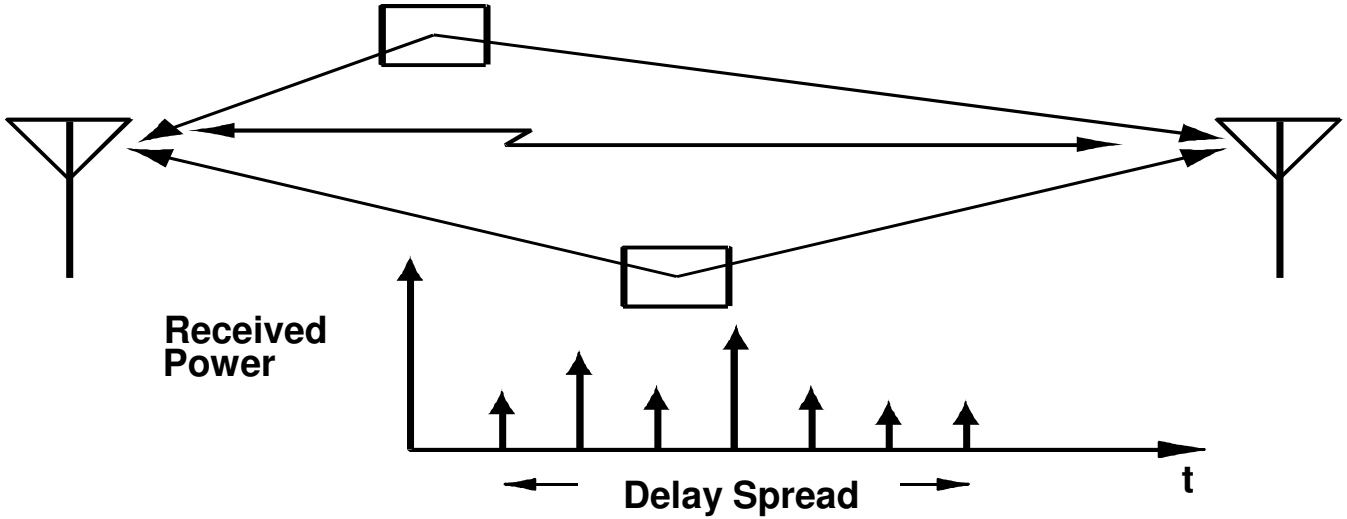
3 km/hr

30 km/hr

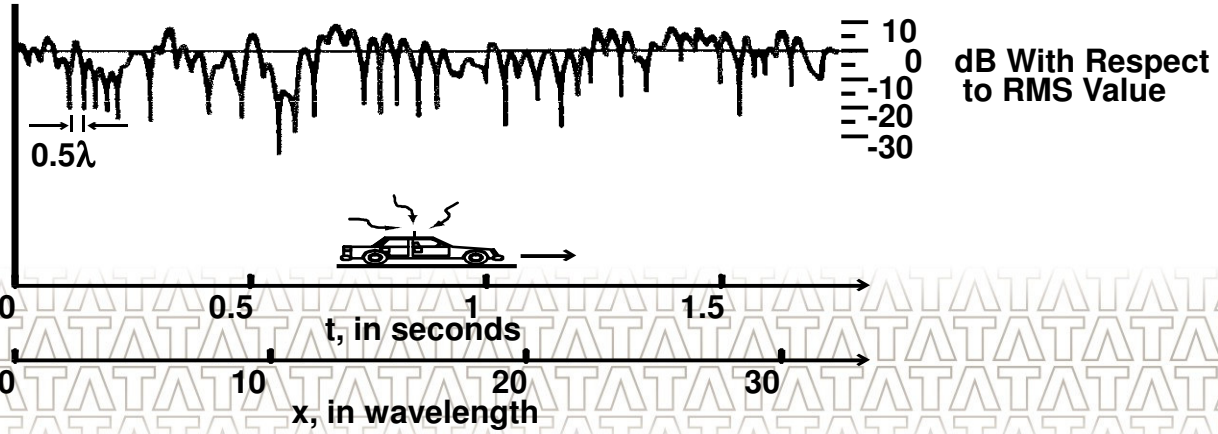
120 km/hr

Can only predict the average of the channel fluctuations, not the instantaneous values

Multipath



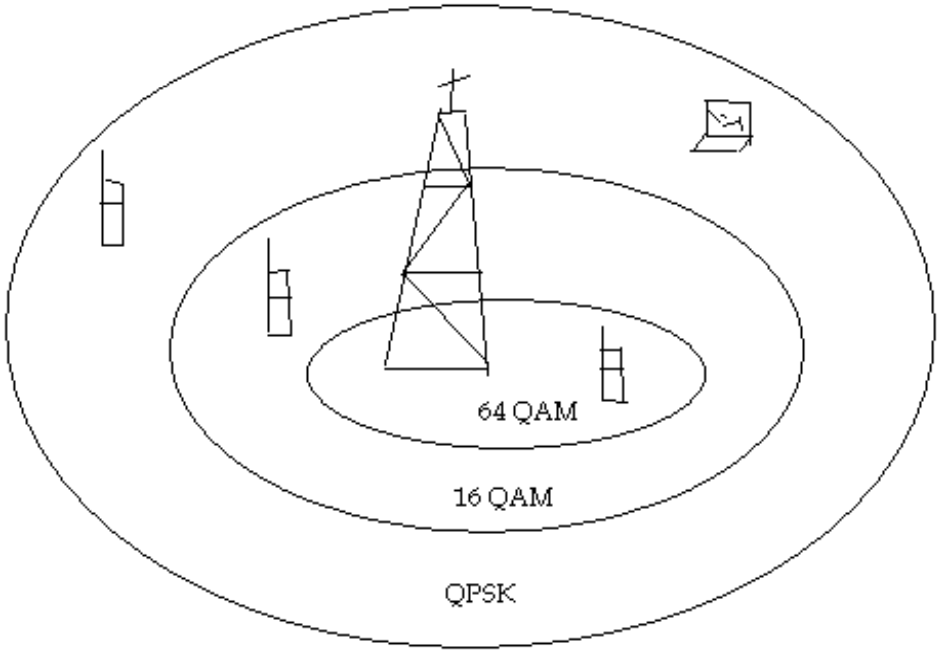
$$h(t) = \sum a_i e^{j\theta_i} \delta(t-t_i)$$



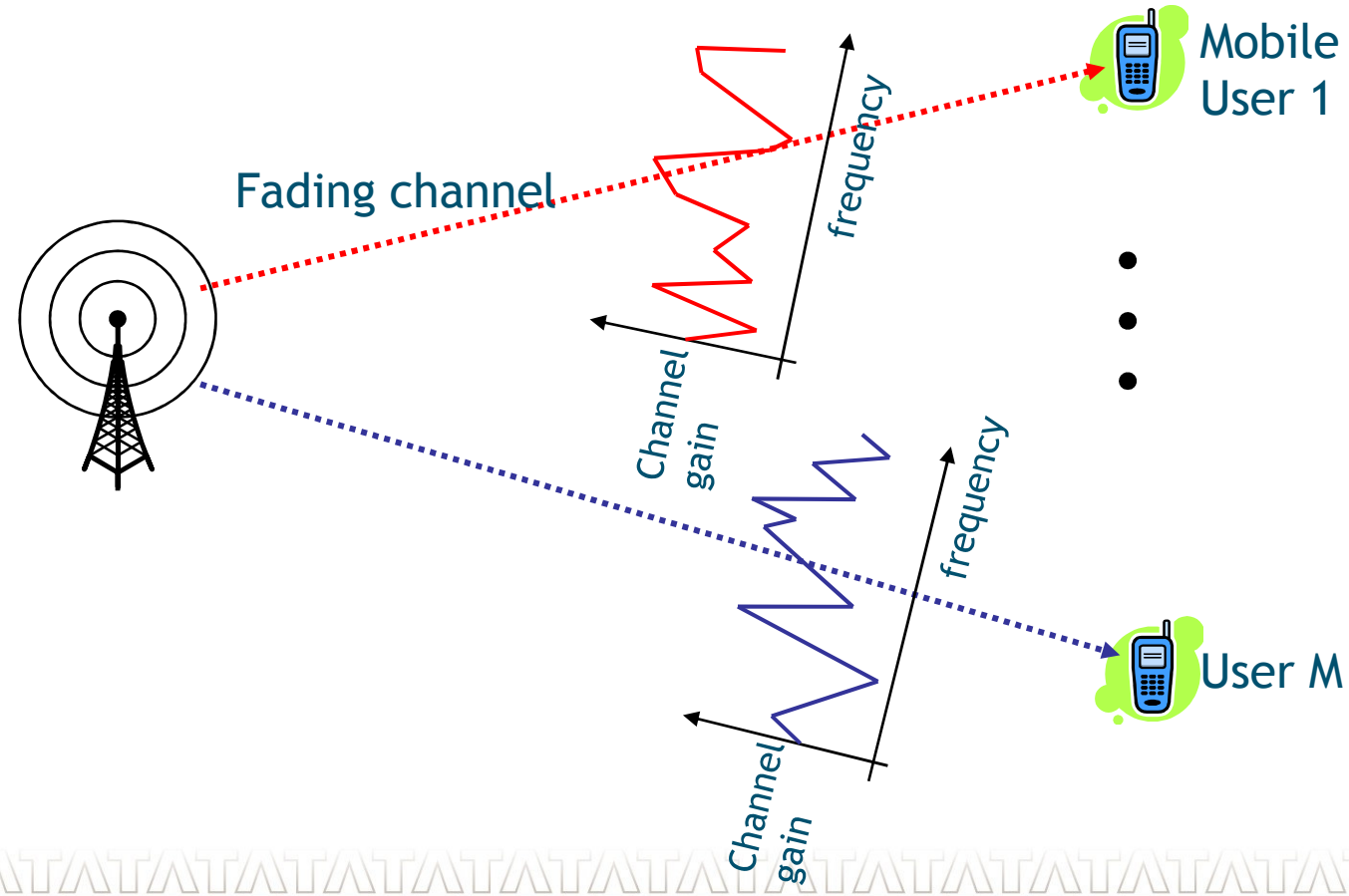
Link Adaptation

Adjust the transmit parameters according to the user's channel characteristics

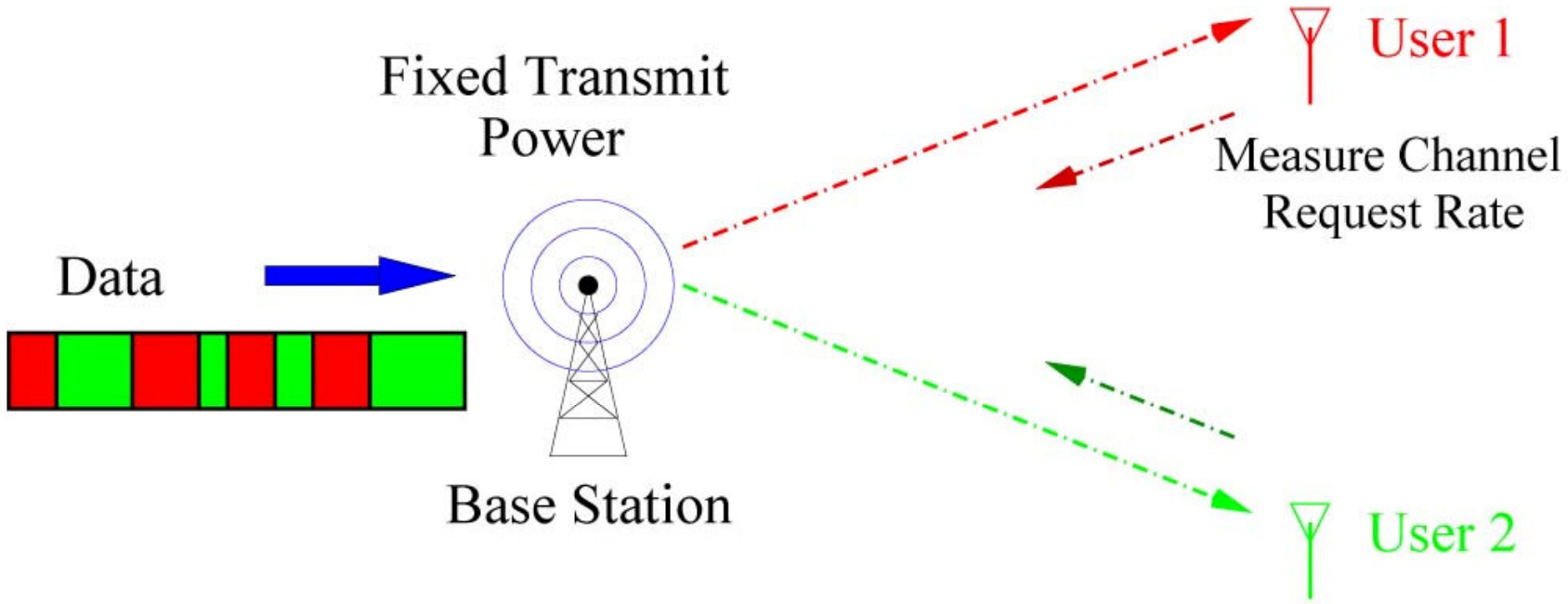
Higher order modulation and error control coding when channel is good ⟶ **Adaptive Modulation and Coding (AMC)**



Opportunistic Communication in Multi-Carrier Systems

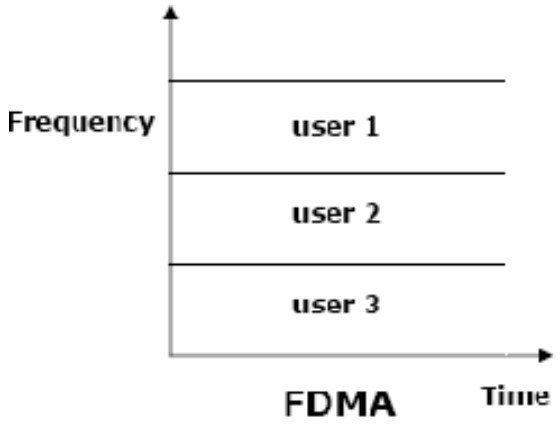


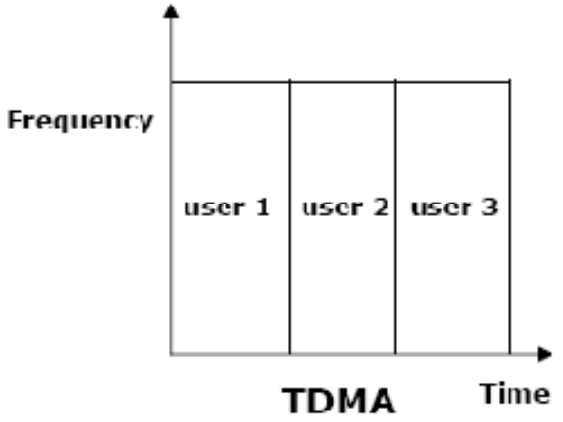
Benefit of Multi-user Diversity

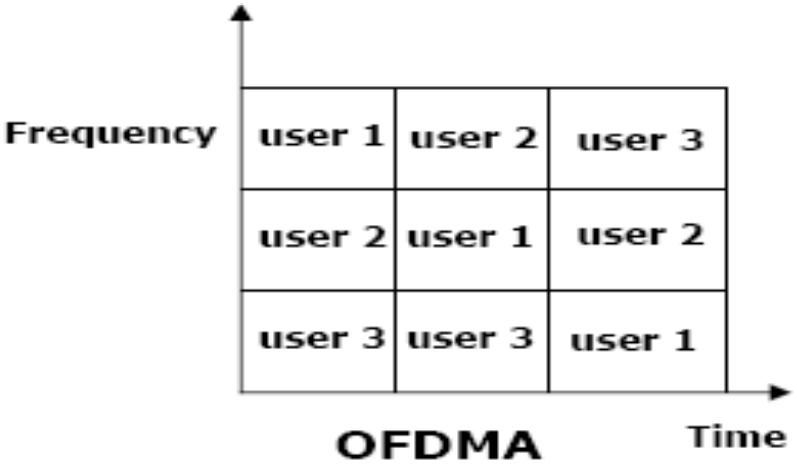


Multiuser diversity provides a system-wide benefit. Challenge is to share the benefit among the users in a fair way

Multiple Access

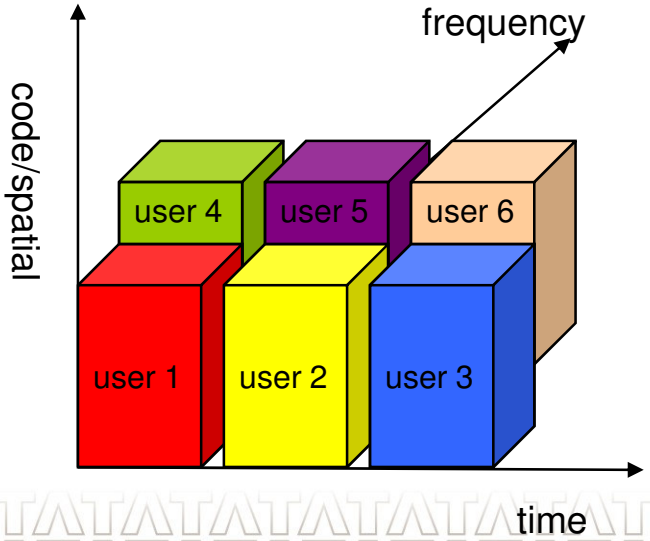






Resource Allocation in Wireless Systems

- High data rate transmission
  - Wireless local area networks (WLAN) 54 -- 108 Mbps
  - Metropolitan area networks (WiMAX) ~10 -- 100 Mbps
  - Cellular systems (3GPP) ~1 -- 4 Mbps
- Limited resources shared by multiple users
  - *Transmit power*
  - *Frequency bandwidth*
  - Transmission time
  - Code resource
  - *Spatial antennas*
- Resource allocation impacts
  - Power consumption
  - User throughput
  - System latency



Scheduling

- Resource sharing always results in contention
- A scheduling discipline resolves contention
- Key to scheduling is to fairly share resources and to provide performance guarantees
- A scheduling discipline does two things:
  - ✓ decides service order
  - ✓ manages queue of service requests
- Where?
  - ✓ Anywhere where contention may occur
  - ✓ At every layer of protocol stack
  - ✓ Usually at network or MAC layer

Introduction to QoS

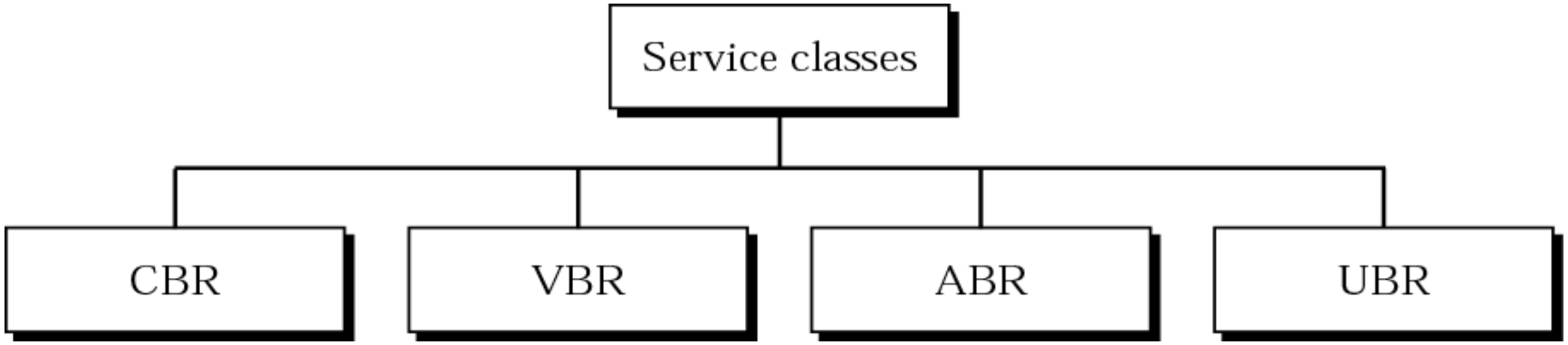
QoS is the well defined and controllable behavior of a system with respect to quantitative parameters.

- Generic parameters:
  - ✓Bandwidth
  - ✓Delay
  - ✓Jitter
  - ✓Packet loss rate (or loss probability)

- Transport/Application-specific parameters:
  - ✓Timeouts
  - ✓Percentage of “important” packets lost

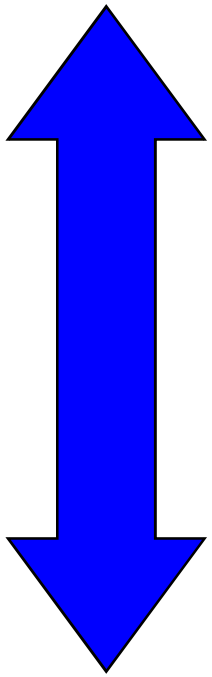
QoS Service Classes

QoS service classes define the priority of the users.



Cross-layer Design: New Paradigm

- **Application**
- **Network**
- **Access**
- **Link**
- **MAC**
- **Hardware**



Diversity
Adaptivity
Scheduling
End-to-End Metrics

Substantial gains in throughput, efficiency, and QoS can be achieved with cross-layer adaptation

Game Theory in Wireless Communication

- Game theory is the study of the interaction of autonomous agents.
- Game Theory is the best known tool to analysis the behavior of distributed systems where the entities can be co-operative or non co-operative and the system does not have any centralized controller. e.g. ad hoc networks
- An ad hoc network is a self-configuring, multihop network in which there is no central authority. Thus, every aspect of the configuration and operation of an ad hoc network must be completely distributed.

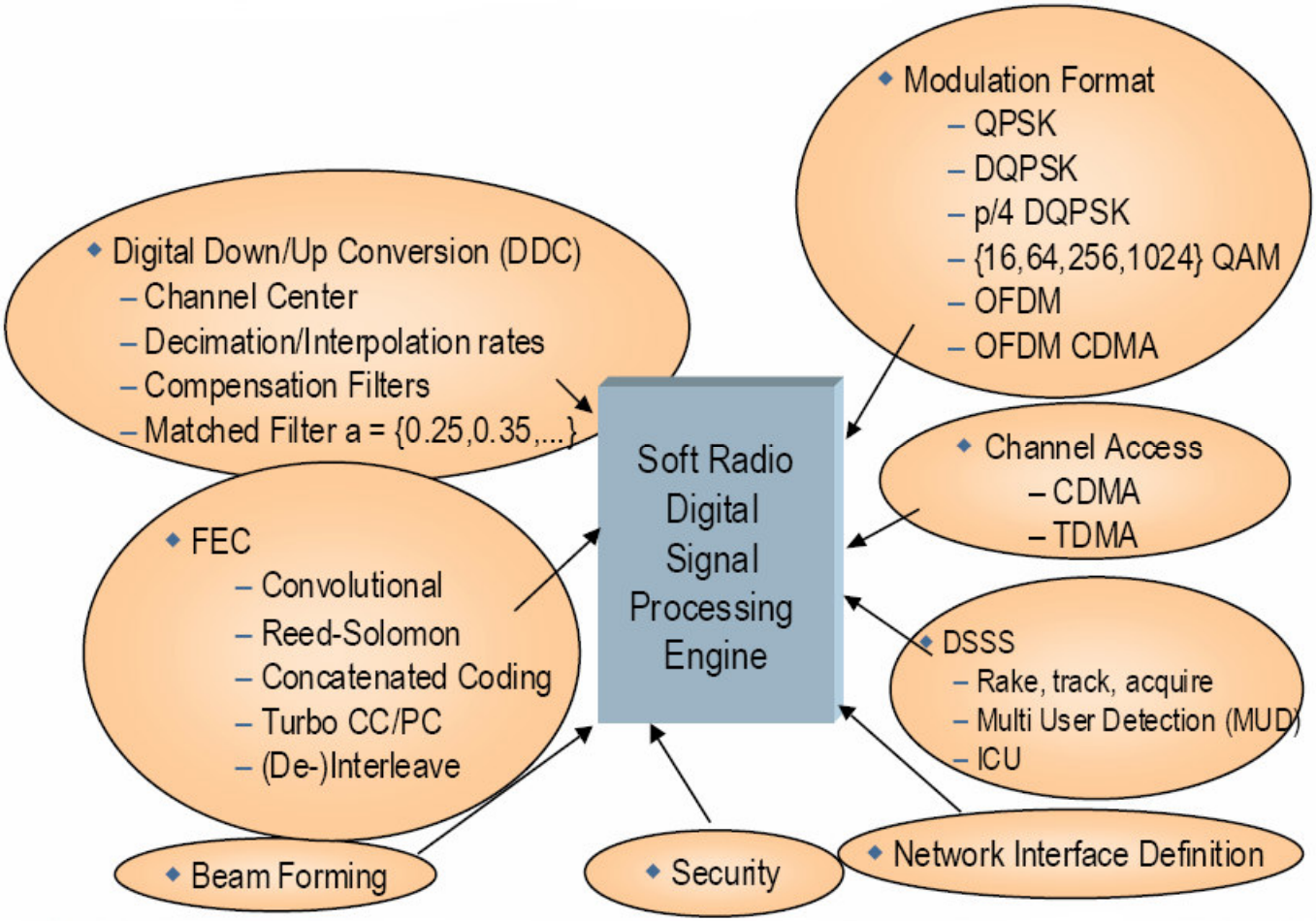
Where to use Game Theory?

- **Power Control :** In CDMA systems, When a player increases his power level, this will increase his own SINR, but will decrease the SINRs of all other players.
- **Routing:** Routing Decision of one node affects the decision of other node.
- **Resource allocation and scheduling:** If every user wants to maximize its own pay-off , totally unfair system, stability will be severely hamper.
- **Inter-cell Interference Management:** Increasing the transmit power of one cell increases interference of neighborhood cells.

Software Defined Radio (SDR)

- The term *software defined radio (SDR)* refers to reconfigurable or reprogrammable radios that can show different functionality with the same hardware.
- The functionality is defined in software, a new technology can easily be implemented in a software radio with a software upgrade.
- In a SDR, multiple waveforms can be implemented in software, using the same hardware.
- SDR provides software control of variety of modulations, FEC, interference management and capacity enhancement techniques over a broad frequency spectrum (wide and narrow band), while ensuring secure communication management.

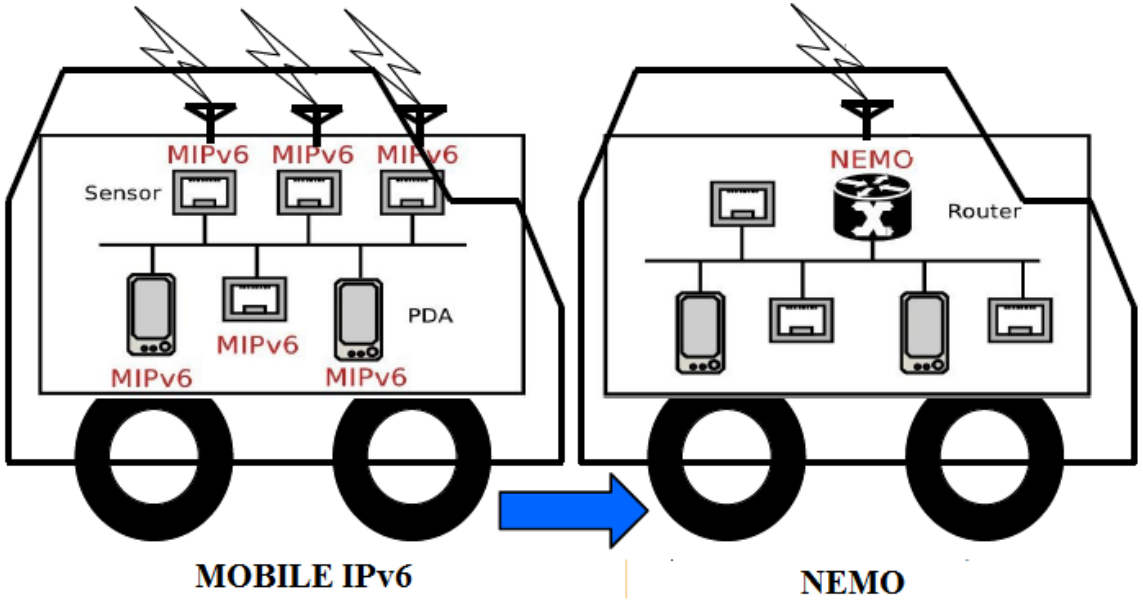
Software Defined Radio Configuration



Network Mobility (NeMO)

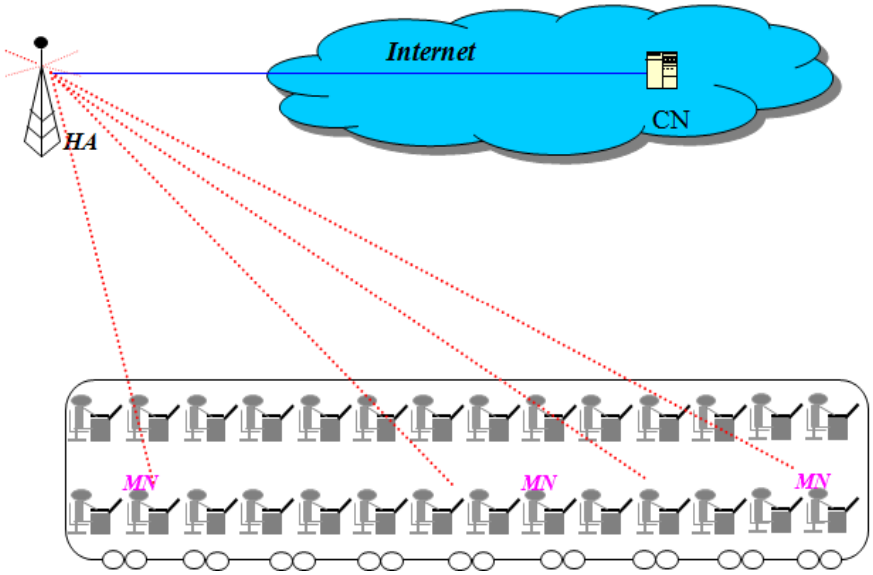
- Network mobility (NeMO) management concerns with the mobility management of an entire wireless mobile network to provide uninterrupted network connectivity to many mobile devices moving together in the mobile network.
- Most of the 3G and entire 4G and beyond wireless communication technology is all-IP.
- This growing use of IP devices in portable applications has created the demand for mobility support for entire networks of IP devices.
- NeMO solves this problem by extending Mobile IP.

Contd…

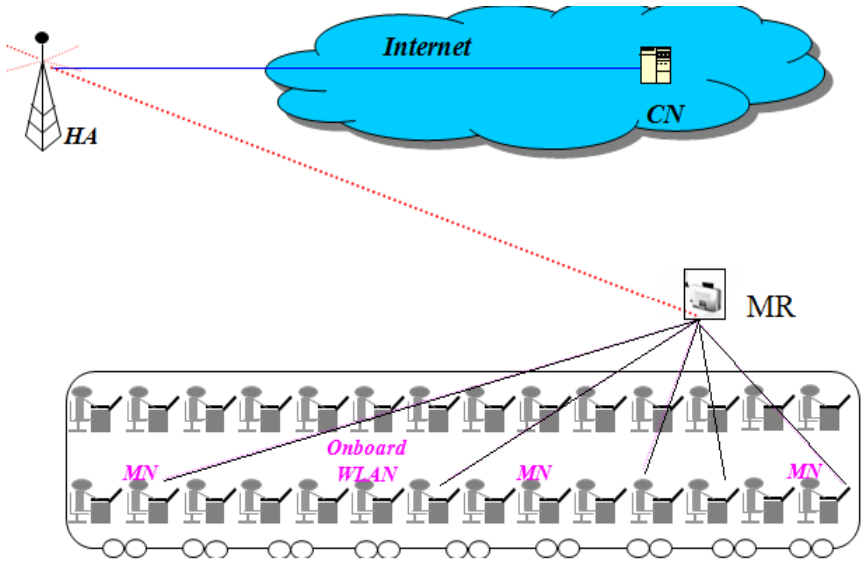

MIPv6
MIPv6
MIPv6
Sensor
MIPv6
MIPv6
PDA
MIPv6
NEMO
Router
MOBILE IPv6
NEMO

Contd…

MIPv6



NeMO



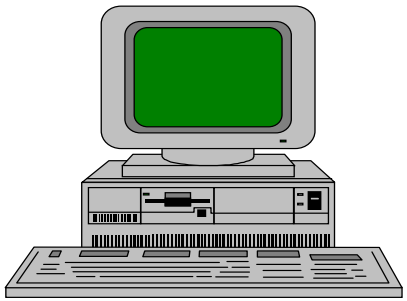
Ubiquitous Computing

Ubiquitous Computing

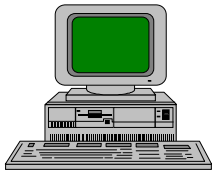
- What Ubiquitous Computing is
  - ✓ Computing is so profound to disappear into background of our lives
- What Ubiquitous Computing isn't
  - ✓ virtual reality
- Difference
  - ✓ virtual reality puts people inside a computer-generated world
- ubiquitous computing forces the computer to live out here in the world with people

The Trends in Computing Technology

1970s



1990s



Late 1990s

Now and Tomorrow ?

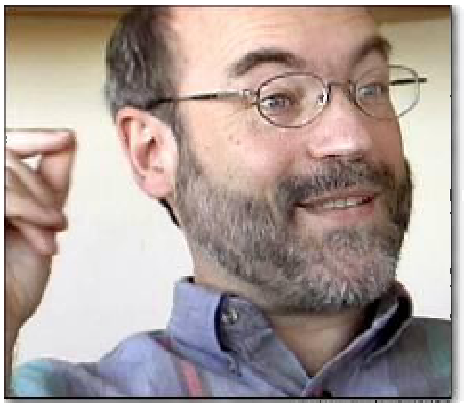
Ubiquitous Computing Era

Broad Concepts that Come from our Assumptions

- Ubiquitous computing and communication connect people to information that exists everywhere.
- Computing is everywhere.
- Sensors and actuators are everywhere.
- Smart applications pro-actively deliver services and information.

Ubiquitous Computing
Mark Weiser, Xerox PARC 1988

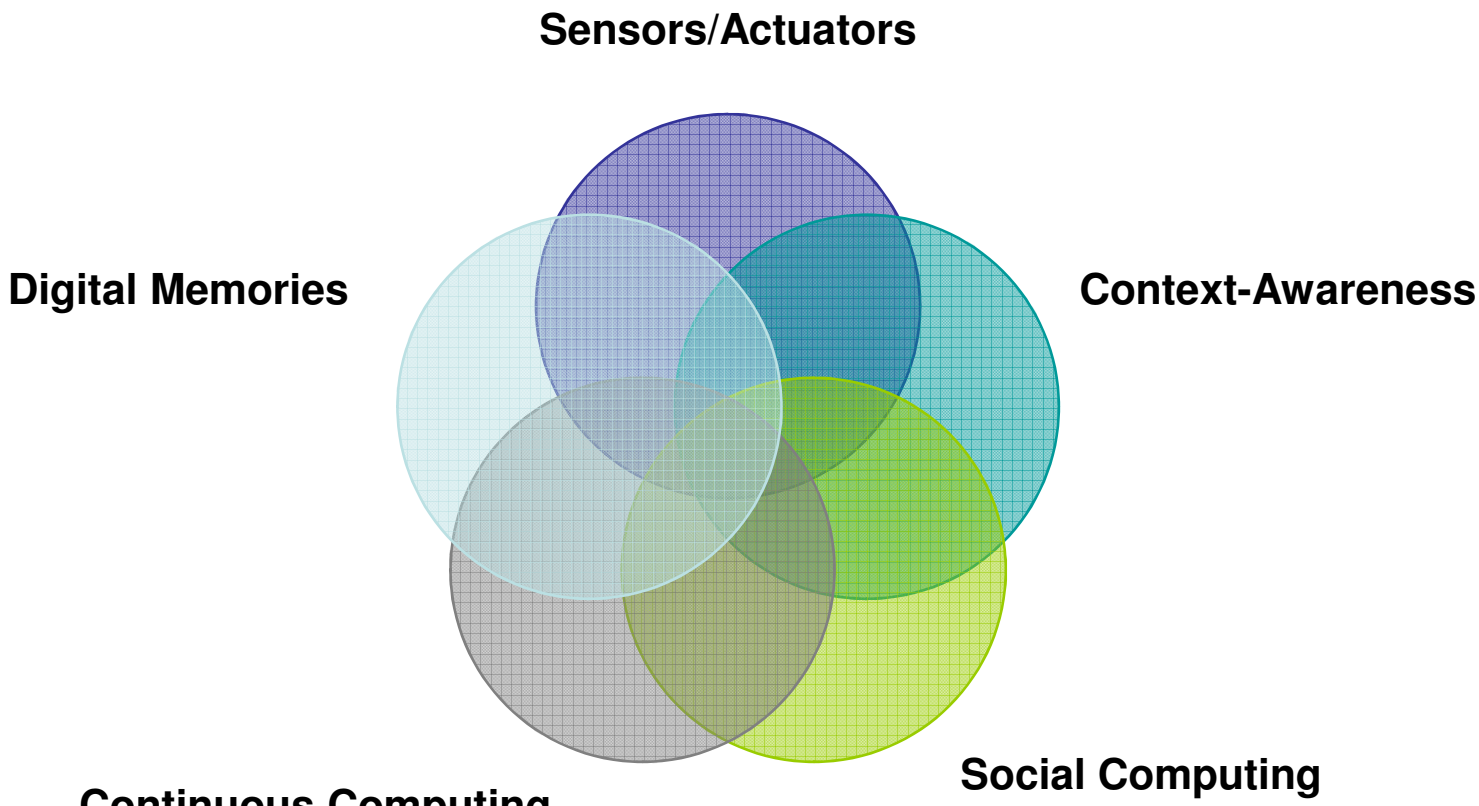
"Ubiquitous computing enhances computer use by making many computers available throughout the physical environment, but making them effectively invisible to the user"



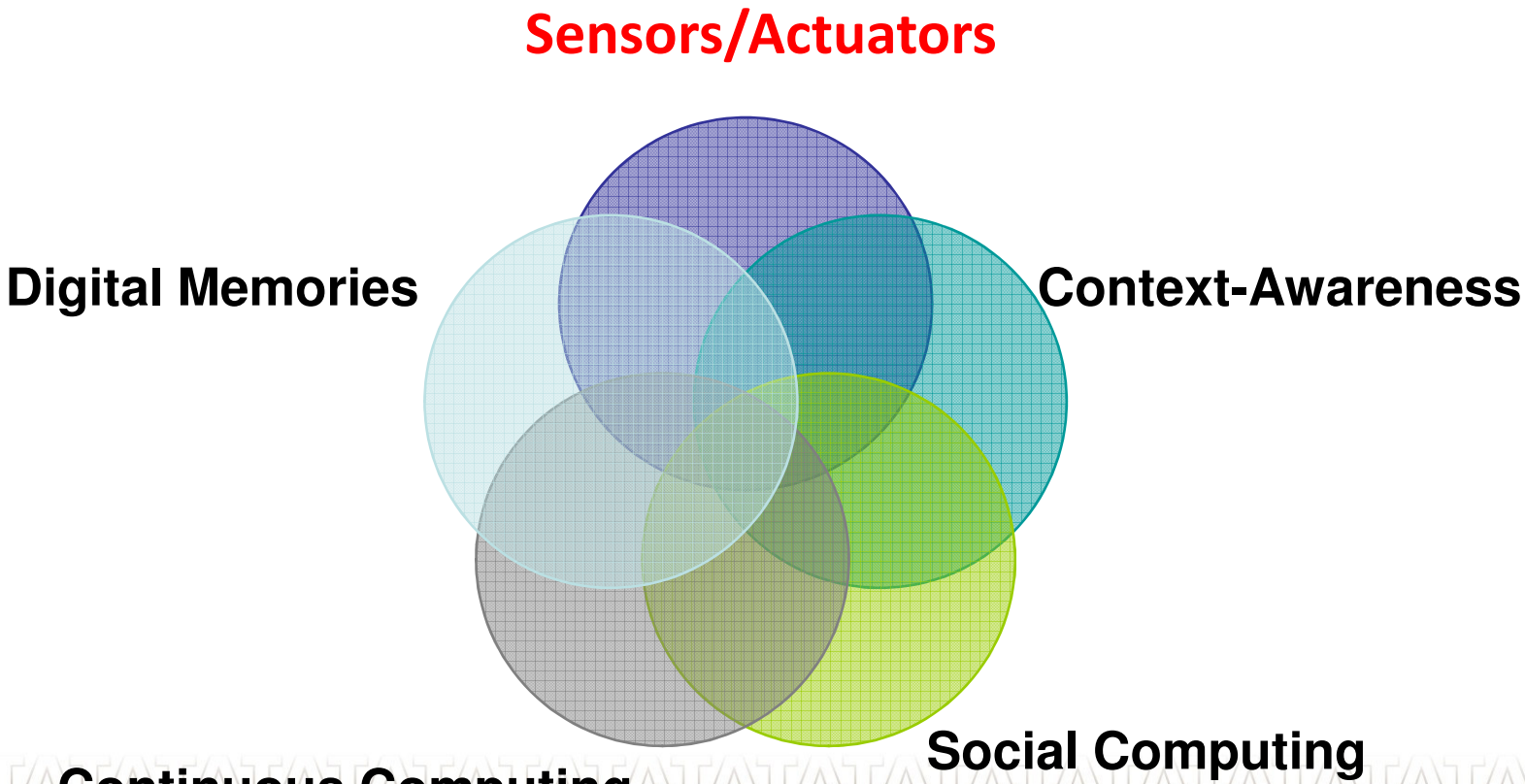
A Good Technology Is Invisible

- "Invisible" stays out of the way of itself
  - Like a good pencil stays out of the way of the writing
  - Like a good car stays out of the way of the driving
- Bad technology draws attention to itself, not task
  - Like a broken, or skipping, or dull pencil
  - Like a car that needs a tune-up
- Computers are mostly not invisible
  - They dominate interaction with them
- *Ubiquitous computing* is about "invisible computers"

The Building Blocks

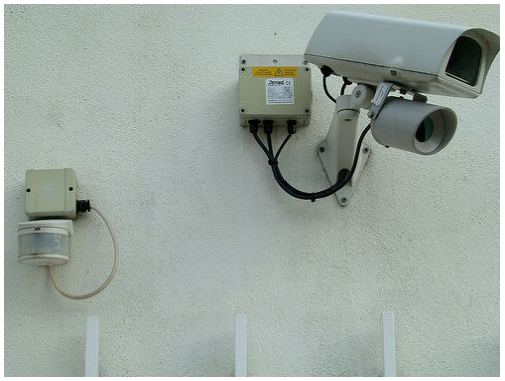


Sensors/Actuators

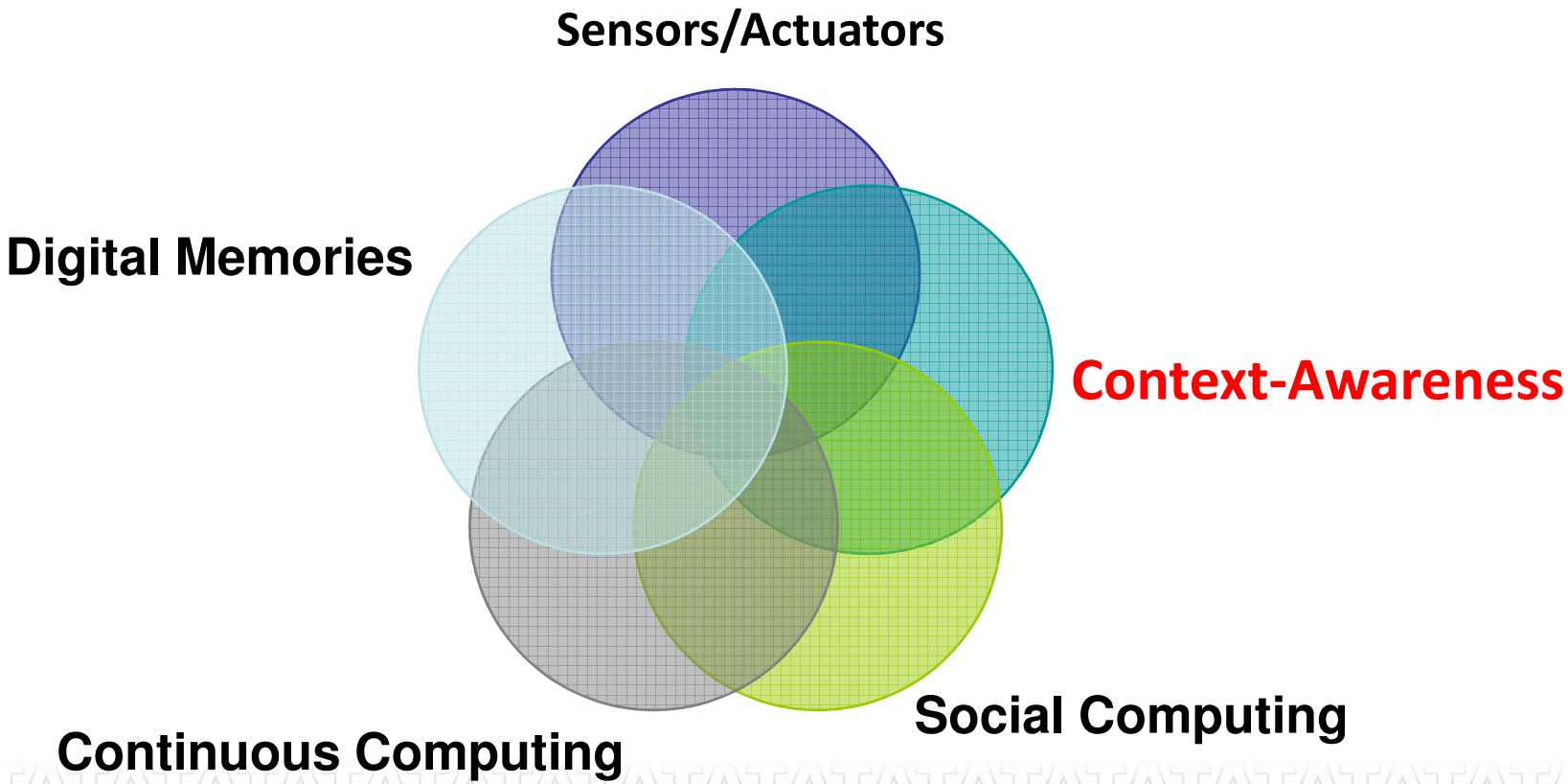


Sensors and Actuators

- Pervasive, online and integrated.
- Sensors inform applications and services, providing context.
- Actuators allow intelligent applications to control the environment.



Context Awareness



Context Awareness

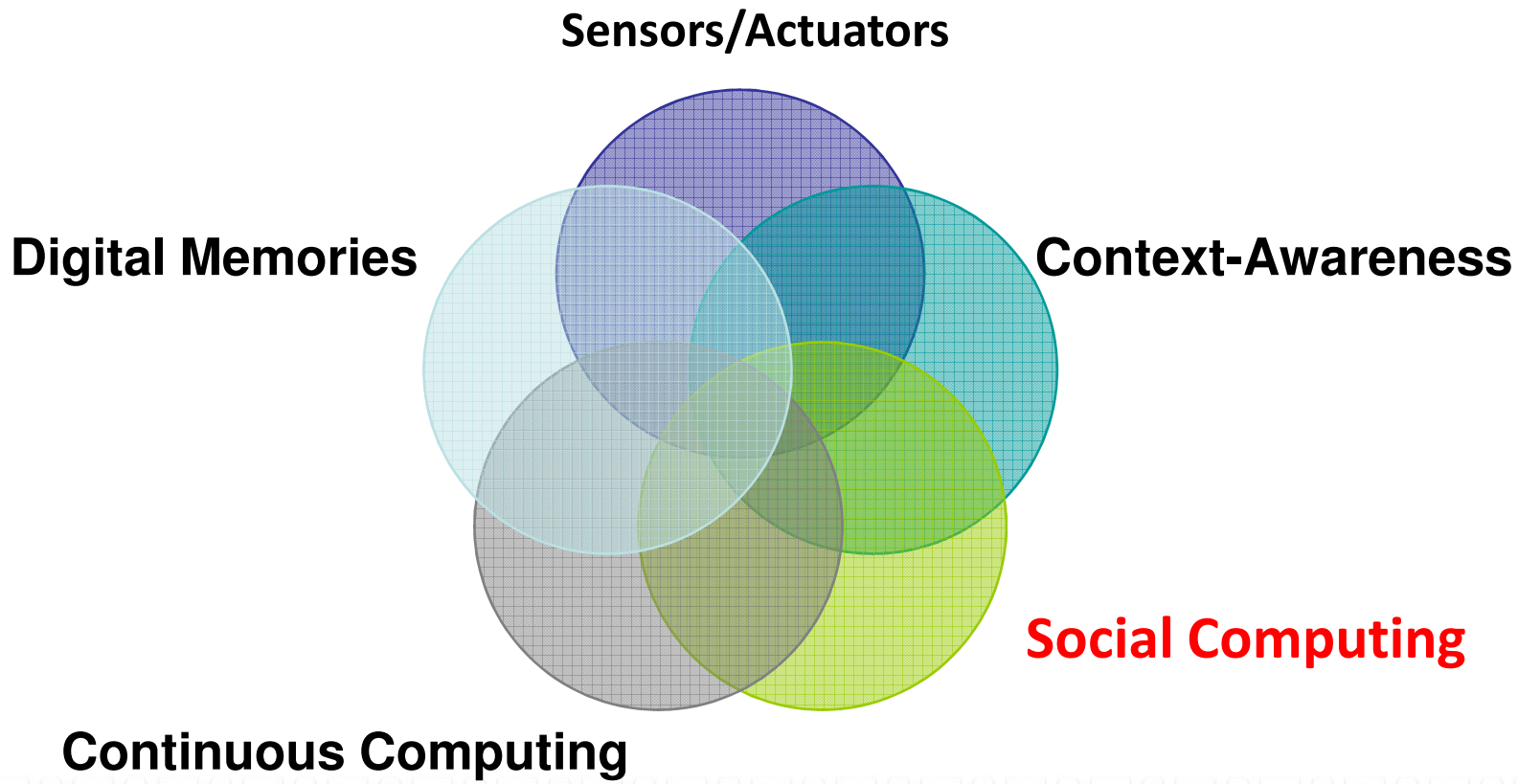
Systems “aware” of, and respond to, their context (situation, environment)

- Physical context
  - location
  - orientation
  - date and time
  - temperature
  - humidity
  - device capabilities
- Logical context
  - Interests
  - user preferences
- Derived/inferred context
  - History
  - Activity

General Mechanism for Context Awareness

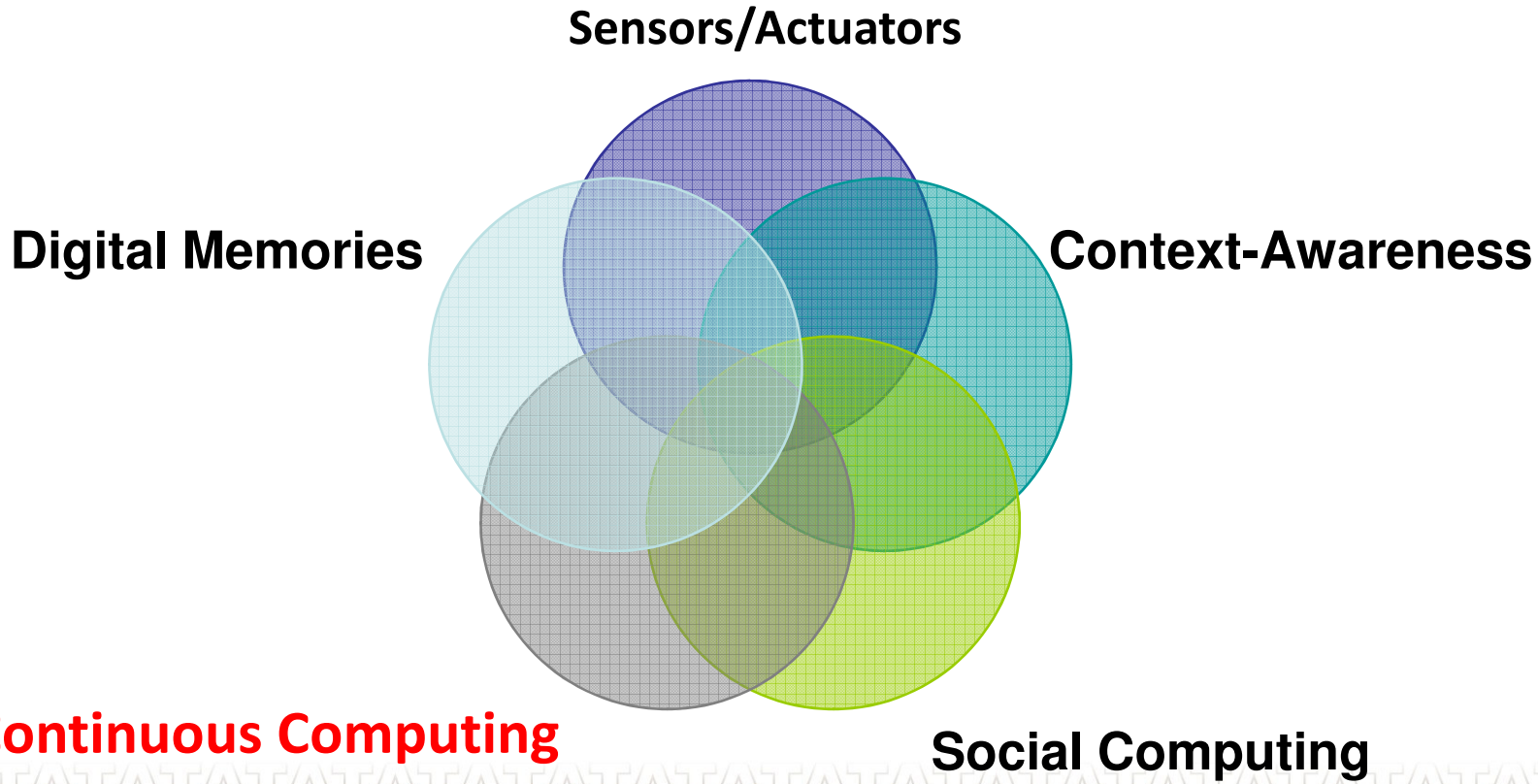
1. Collect information on the user's physical, informational or emotional state.
2. Analyze the information, either by treating it as an independent variable or by combining it with other information collected in the past or present.
3. Perform some action based on the analysis.
4. Repeat from Step 1, with some adaptation based on previous iterations.

Social Computing



Social Computing

Continuous Computing



Continuous Computing is…

- Pervasive networks
- Smart spaces
- Mobile devices
- Advanced application services

Next Generation Smart Spaces

Better human computer interaction

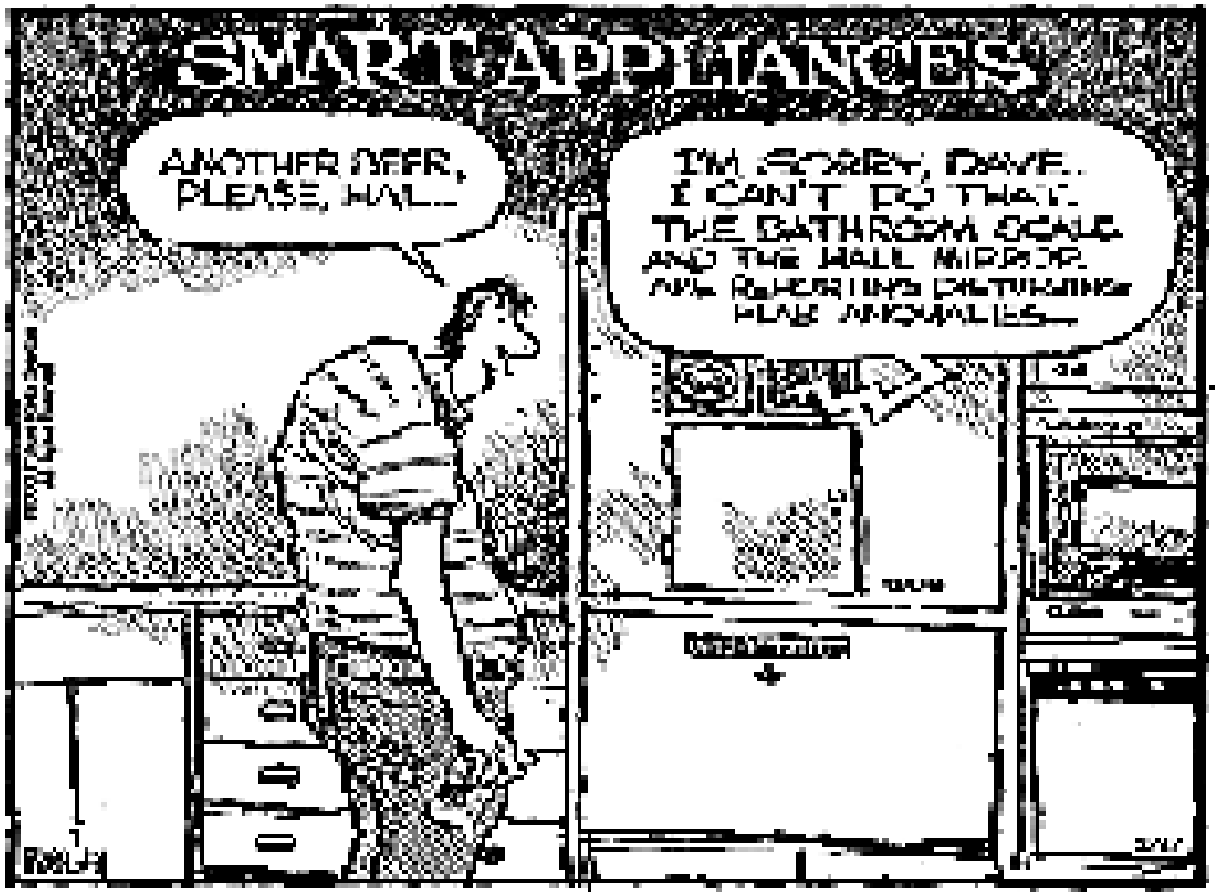
Oxygen, MIT Media Lab

This…

Will become this

Eventually, living in a world of continuous computing will be like wearing eyeglasses: the rims are always visible, but the wearer forgets she has them on—even though they're the only things making the world clear

Intelligent Environment



Ubiquitous Computing Projects

- **Aura project** Carnegie Mellon Univ.
  - Distraction-free ubiquitous computing
- **Endeavour** Univ. of California at Berkeley
- **Oxygen** MIT
- **Portolano** The Univ. of Washington
  - Infrastructure based on mobile agents, data-centric routing
- **Sentient Computing** AT&T lab.
- **Cooltown** HP
  - Extending Web technology, wireless networks, and portable devices
- **EasyLiving** Microsoft Research
- **WebSphere** Everyplace IBM
  - Application and middleware to develop application in business level

An interconnected system

TCS

Home Gateway Initiative

Home Networking

- Lots of companies producing WiFi gateways
  - Growing market worldwide
  - Prices falling rapidly
  - Technology changing rapidly

- Consumer electronics companies WiFi enabling devices

SONY

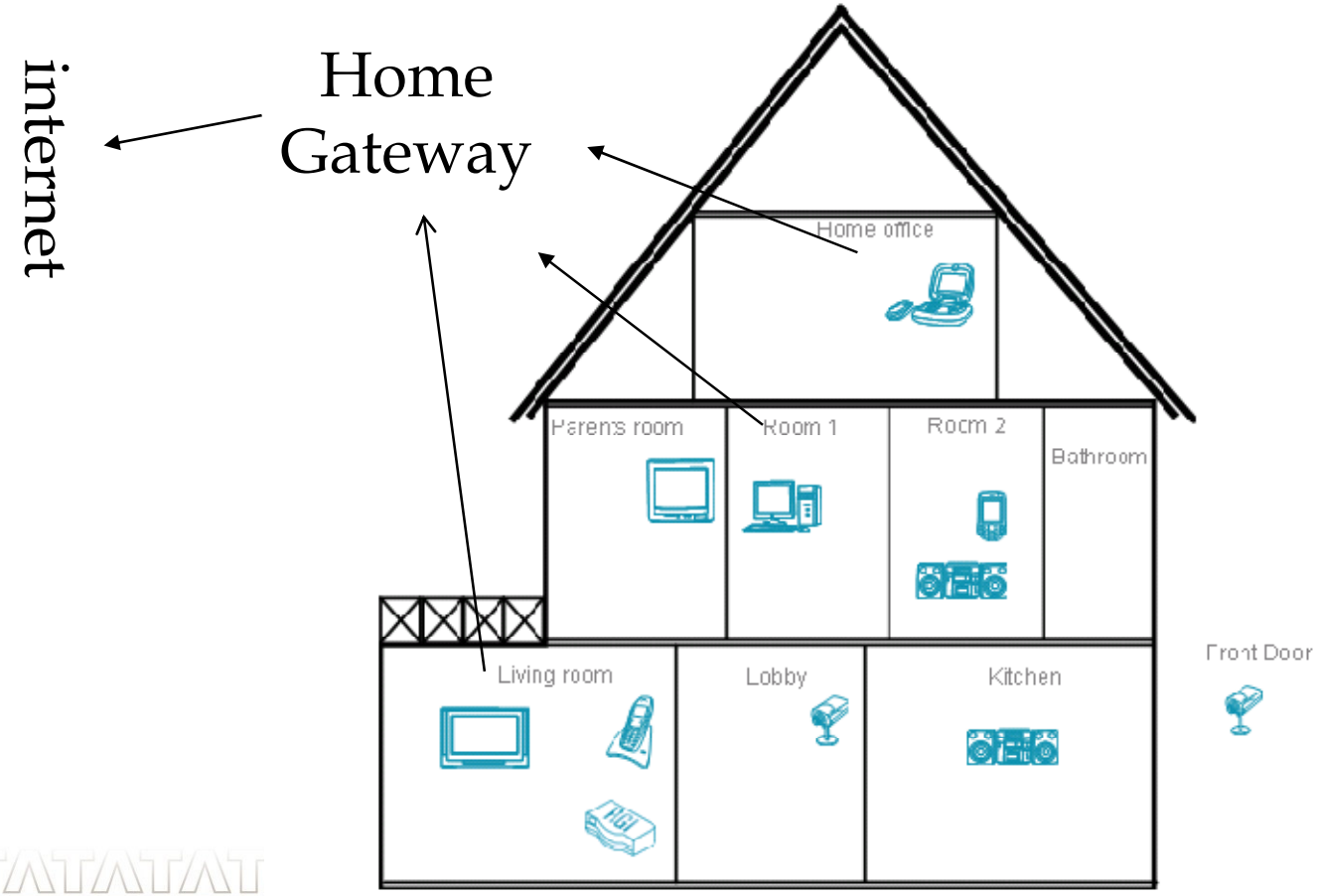
Microsoft

PHILIPS

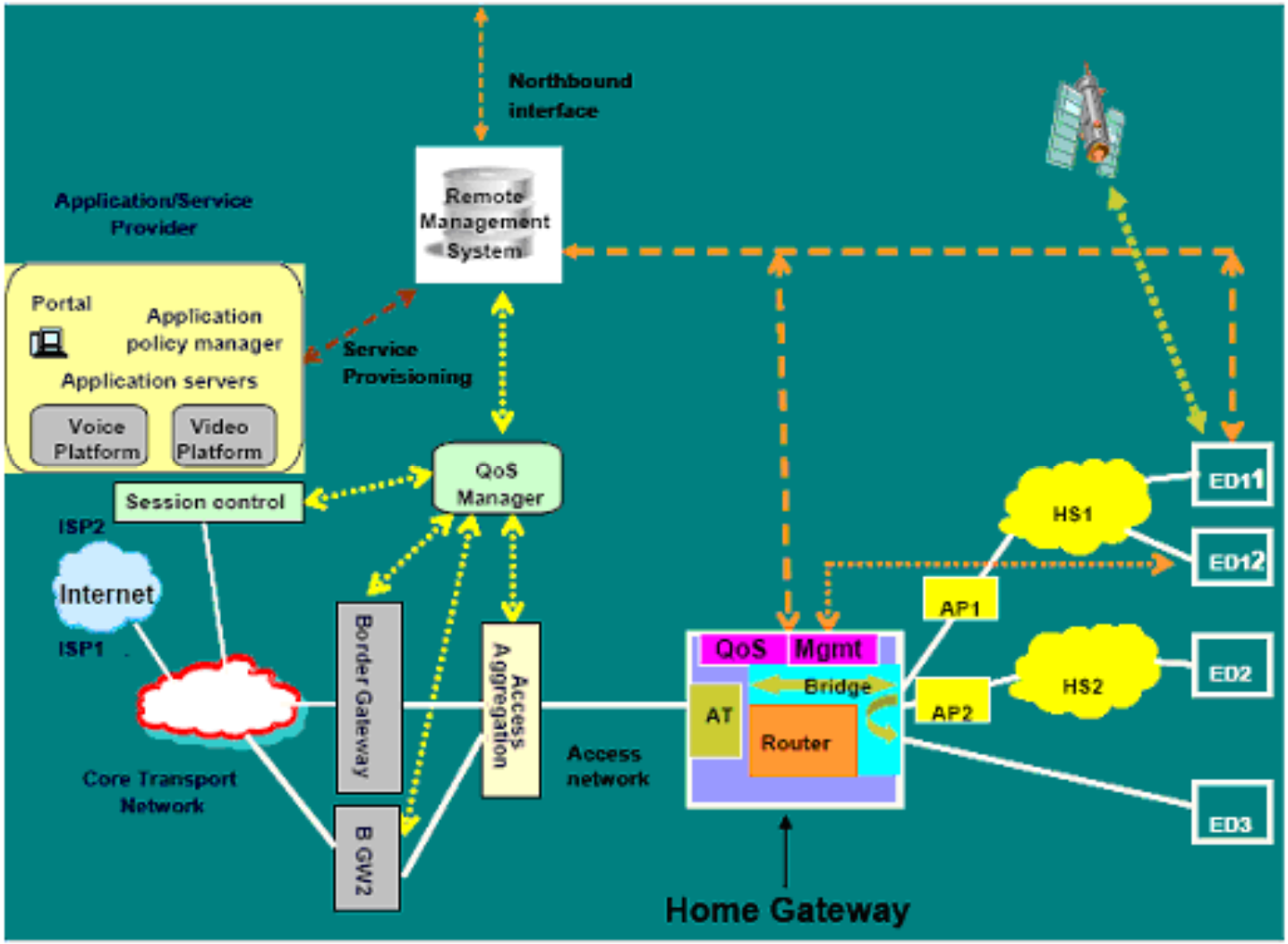
Home Gateway

- Home Gateway (HG) is an intelligent broadband or networking interface device designed to act as a hub for homes and small offices.
- All HGs should have the common characteristics that any in-home device must be able to communicate with the Access network except for the hybrid mode architecture.
- Any in-home device must be able to communicate with any other in-home device without the traffic going via the access network for security, privacy, performance and charging reasons.

Home Gateway



Home Gateway Architecture



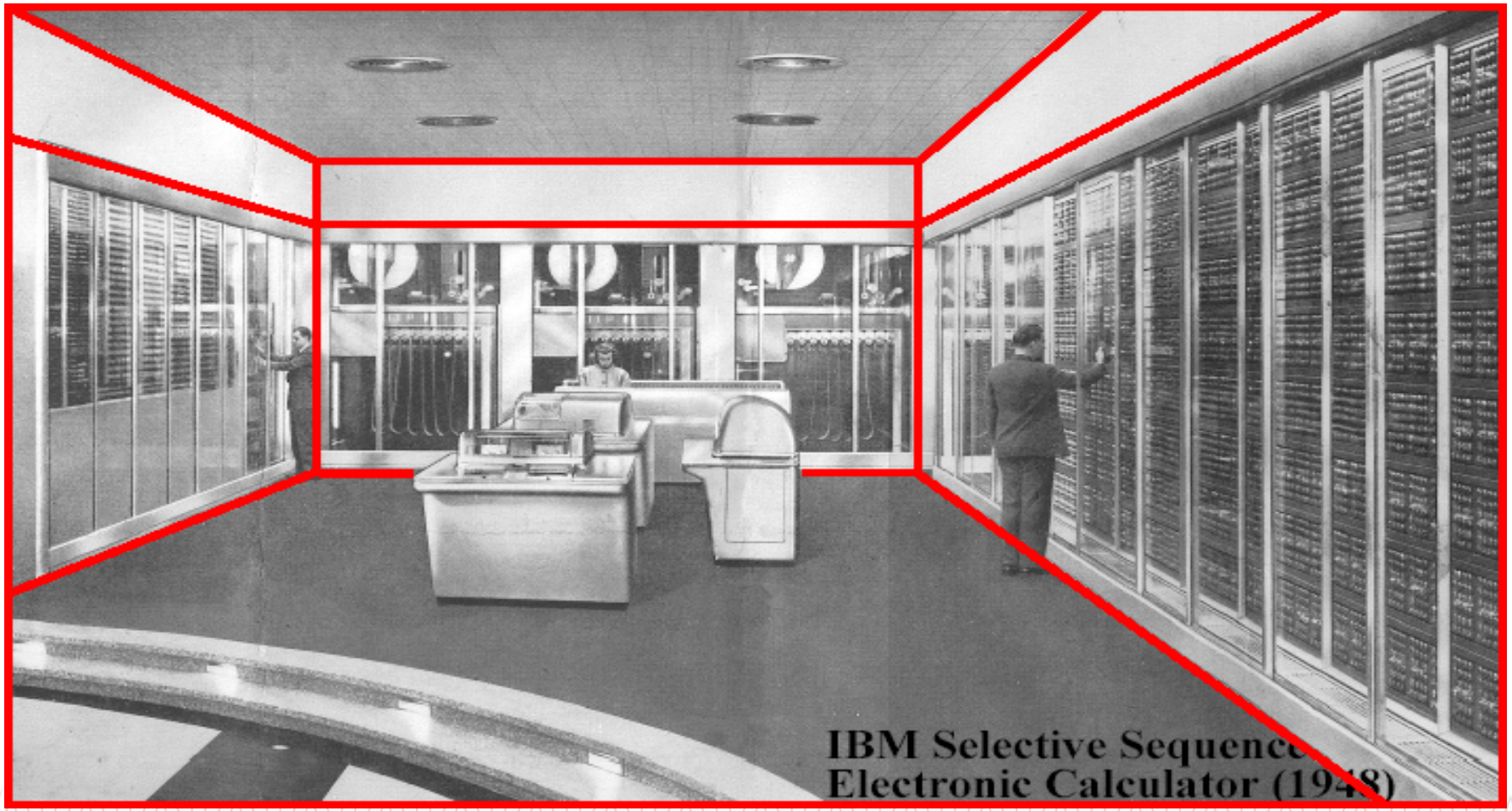
TCS Home Gateway Initiative

- TCS has come up with a home infotainment platform (HIP) – an embedded platform for Internet access on TV from home.
- TCS has plans to extend this device into a ubiquitous home gateway.
- Like all embedded systems, such gateway device is required to store, access, or communicate date which are sensitive in nature. This makes security a serious concern.

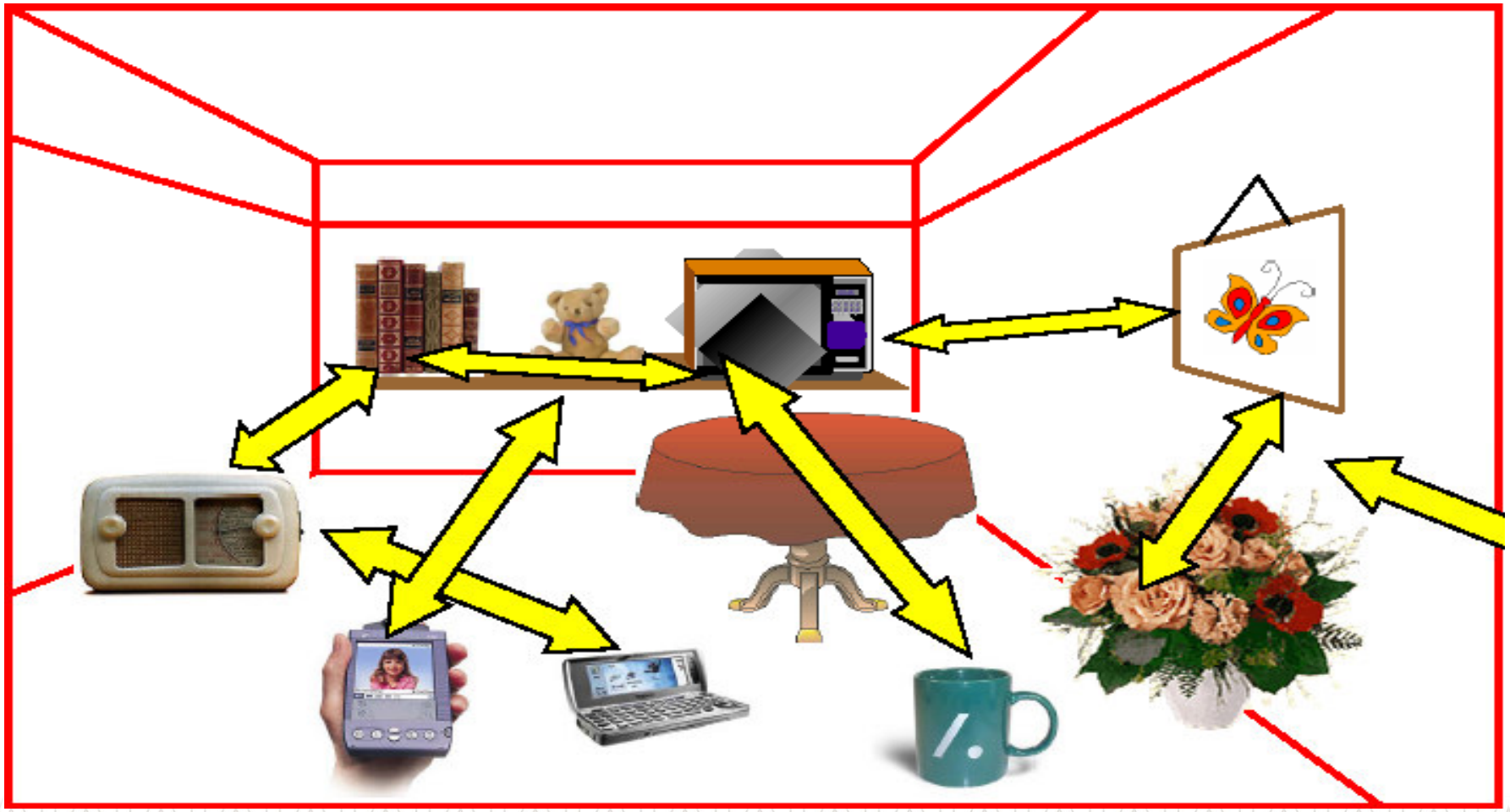
The Big Question…

How will new technology impact the 21st Century?

Yesterday's Computers Filled Rooms ...



… So Will Tomorrow's



Conclusion

- Wireless Network is still evolving.
- What was laid foundation in 1873 by Clerk Maxwell, has taken a long journey to come to this shape.
- Still immense scope of research and development activity is going on.
- **Ubiquitous computing and communication is not the end and perhaps may be the beginning of another journey for wireless communication , networking and computing.**

Thank You