BLG 337E- Principles of Computer Communications

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18/11/ 2014

-Wireless Networks-

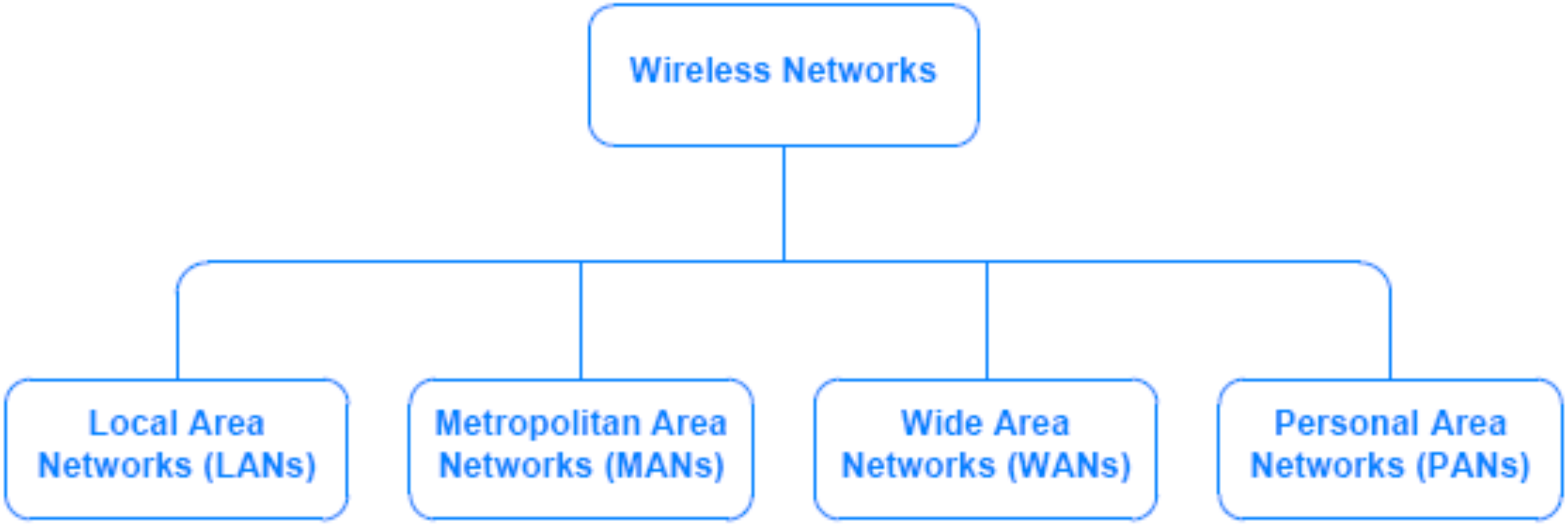
References:

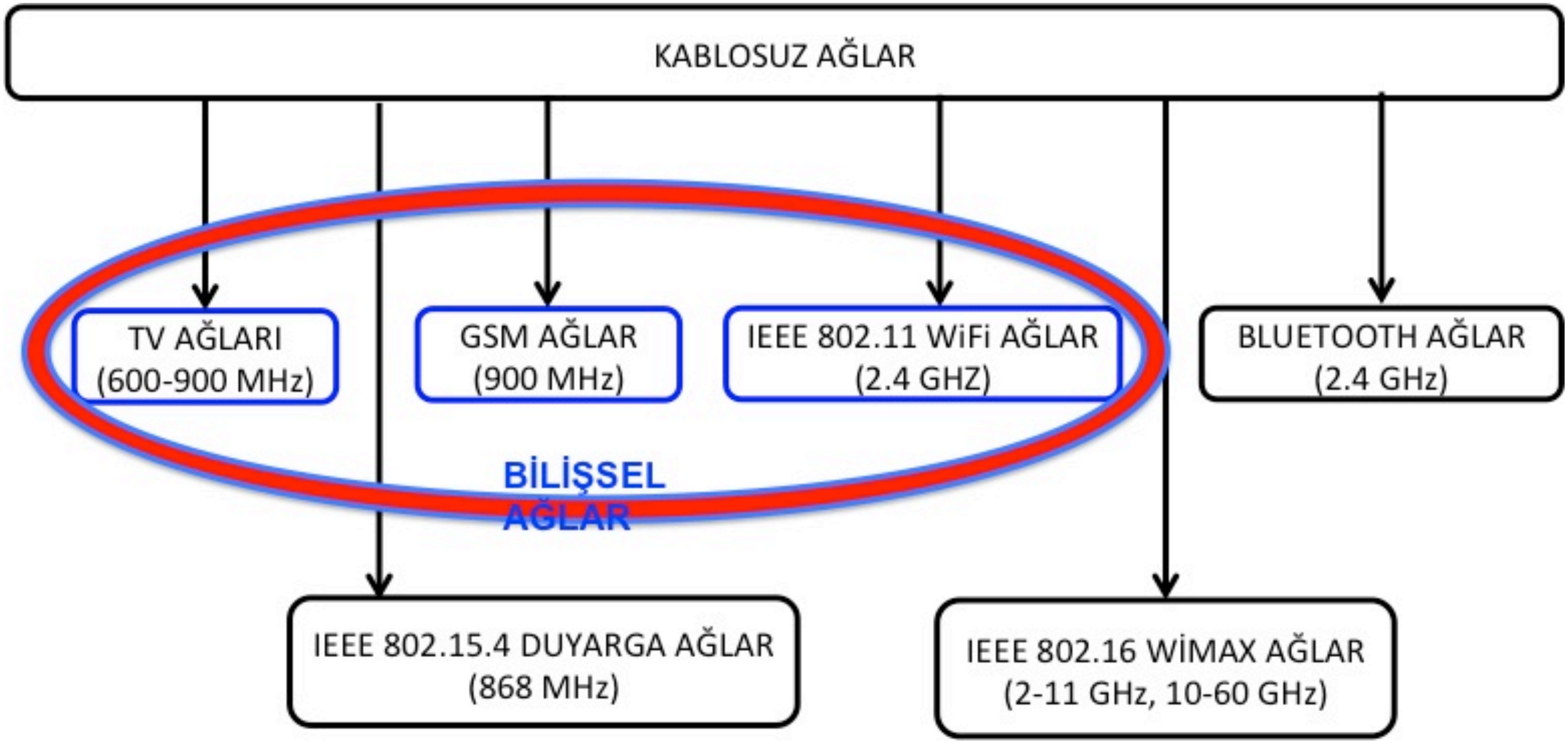
Data and Computer Communications, William Stallings, Pearson-Prentice Hall, 9th Edition, 2010.

-*Computer Networking, A Top-Down Approach Featuring the Internet*, James F.Kurose, Keith W.Ross, Pearson-Addison Wesley, 6th Edition, 2012.

-Google!

A Taxonomy of Wireless Networks



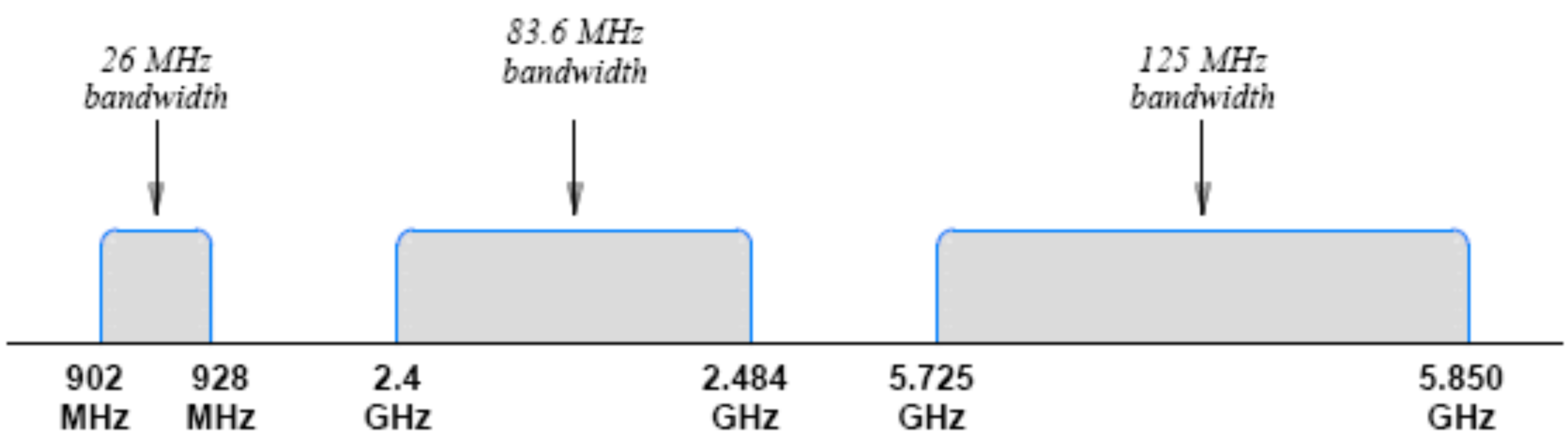

KABLOSUZ AĞLAR
TV AĞLARI
(600-900 MHz)
GSM AĞLAR
(900 MHz)
IEEE 802.11 WiFi AĞLAR
(2.4 GHZ)
BLUETOOTH AĞLAR
(2.4 GHz)
BİLİŞSEL
AĞLAR
IEEE 802.15.4 DUYARGA AĞLAR
(868 MHz)
IEEE 802.16 WİMAX AĞLAR
(2-11 GHz, 10-60 GHz)

Personal Area Networks (PANs)

Type	Purpose
Bluetooth	Communication over a short distance between a small peripheral device such as a headset or mouse and a system such as a cell phone or a computer
InfraRed	Line-of-sight communication between a small device, often a hand-held controller, and a nearby system such as a computer or entertainment center
ISM wireless	Communication using frequencies set aside for Industrial Scientific and Medical devices, an environment where electromagnetic interference may be present

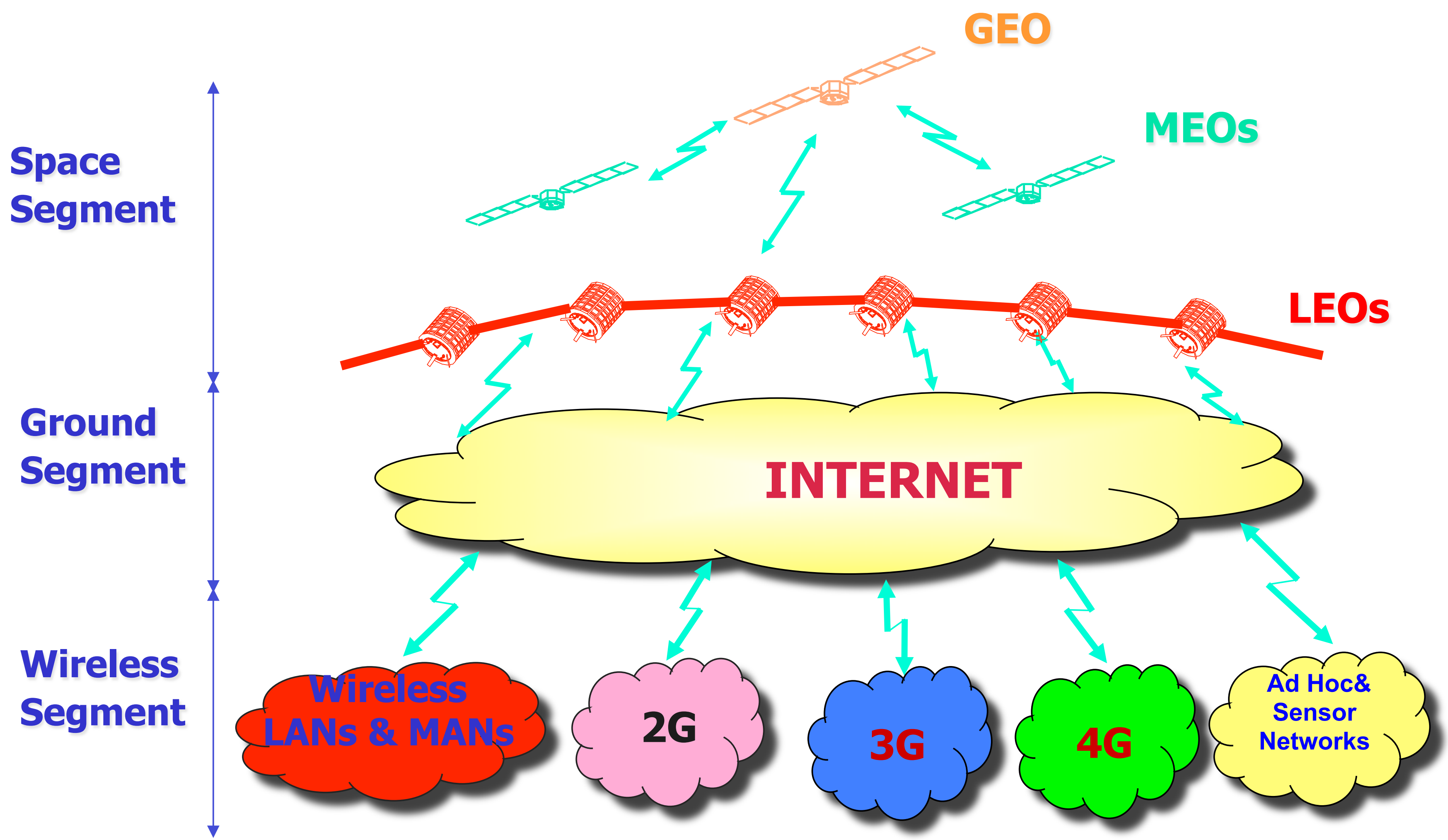
ISM Wireless Bands Used by LANs and PANs

- A region of electromagnetic spectrum is reserved for use by Industrial, Scientific, and Medical (ISM) groups
  - Known as ISM wireless
- The frequencies are not licensed to specific carriers
  - are broadly available for products, and are used for LANs and PANs
- Figure below illustrates the ISM frequency ranges



Name	Frequency range	Applications
Low frequency	30 to 300 kHz	Navigation, time standards
Medium frequency	300 kHz to 3 MHz	Marine/aircraft navigation, AM broadcast
High frequency (shortwave)	3 to 30 MHz	Broadcasting, mobile radio, amateur radio
Very high frequency	30 to 300 MHz	Landmobile,FM/TVbroadcast,amateurradio
Ultra-high frequency	300 MHz to 3 GHz	Cell phones, mobile radio, WLAN, personal-area networks (PANs)
Super-high frequency	3 to 30 GHz	Satellite, radar, backhaul, TV
Extremely high frequency	30 to 300 GHz	Satellite, radar, backhaul, experimental

Overall Picture of Wireless Networking



Overview of Wireless Networks: Evolution of Voice-Oriented Services

Year	Event
Early 1970s	First generation of mobile radio at Bell Labs
Late 1970s	First generation of cordless phones
1982	First generation Nordic analog NMT
1983	Deployment of US AMPS
1988	Initiation of GSM development (new digital TDMA)
1991	Deployment of GSM
1993	Initiation of IS-95 standard for CDMA
1995	PCS band auction by FCC
1998	3G standardization started

FDMA – Frequency Division Multiple Access
NMT – Nordic Mobile Telephony
AMPS – Advanced Mobile Phone System
GSM – Global System for Mobile Communication
TDMA – Time Division Multiple Access

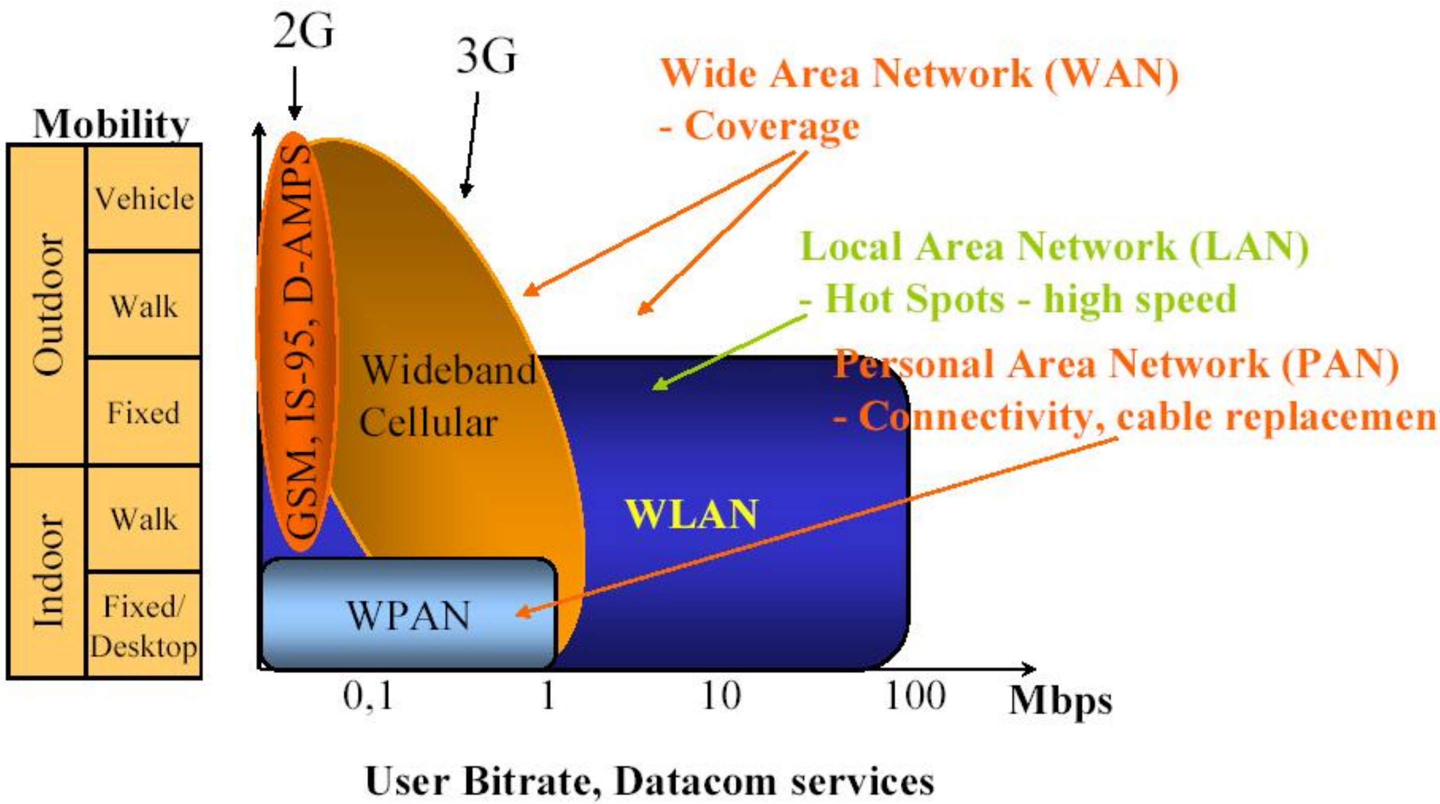
IS-95 – Interim Standard 95
CDMA – Code Division Multiple Access
PCS – Personal Communication System
FCC – Federal Communication Commission

Overview of Wireless Networks: Evolution of Data-Oriented Services

Year	Event
1979	Diffused infrared (IBM Rueschlikon Lab - Switzerland
Early 1980s	Wireless modem (Data Radio)
1990	IEEE 802.11 for Wireless LANs standards
1990	Announcement of Wireless LAN products
1992	HIPERLAN in Europe
1993	CDPD (IBM and 9 operating companies)
1996	Wireless ATM Forum started
1997	U-NII bands released, IEEE 802.11 completed, GPRS started
1998	IEEE 802.11b and Bluetooth announcement
1999	IEEE 802.11a/HIPERLAN-2 started

HIPERLAN – High Performance Radio LAN
CDPD – Cellular Digital Packet Data
U-NII – Unlicensed National Information Infrastructure
GPRS – General Packet Radio Service

Overview of Wireless Networks: Different Generations



Relative coverage, mobility, and data rates of generations of cellular systems and local broadband and ad hoc networks.

1G Wireless Systems
(Analog systems)

- Use two separate frequency bands for forward (base station to mobile) and reverse (mobile to base station) links: Frequency Division Duplex (FDD)
  - AMPS: United States (also Australia, southeast Asia, Africa)
  - TACS: EU (later, bands were allocated to GSM)
  - NMT-900: EU (also in Africa and southeast Asia)
- Typical allocated overall band was 25 MHz in each direction
- Dominant spectra of operation was 800 and 900 MHz bands.

AMPS – Advanced Mobile Phone System
TACS – Total Access Communication System
NMT – Nordic Mobile Telephony

2G Wireless Systems
(Voice Services)

- Digital cellular
  - GSM (EU/Asia): TDMA
  - IS-54 (US): TDMA
  - IS-95 (US/Asia): CDMA
- PCS – residential applications
  - CT-2 (EU,CA): TDMA/TDD
  - DECT(EU):TDMA/TDD
  - PACS (US): TDMA/FDD

CT-2 – Cordless Telephone 2
DECT – Digital Enhanced Cordless Telephone
PACS – Personal Access Communication System

2G Wireless Systems
(Data Services)

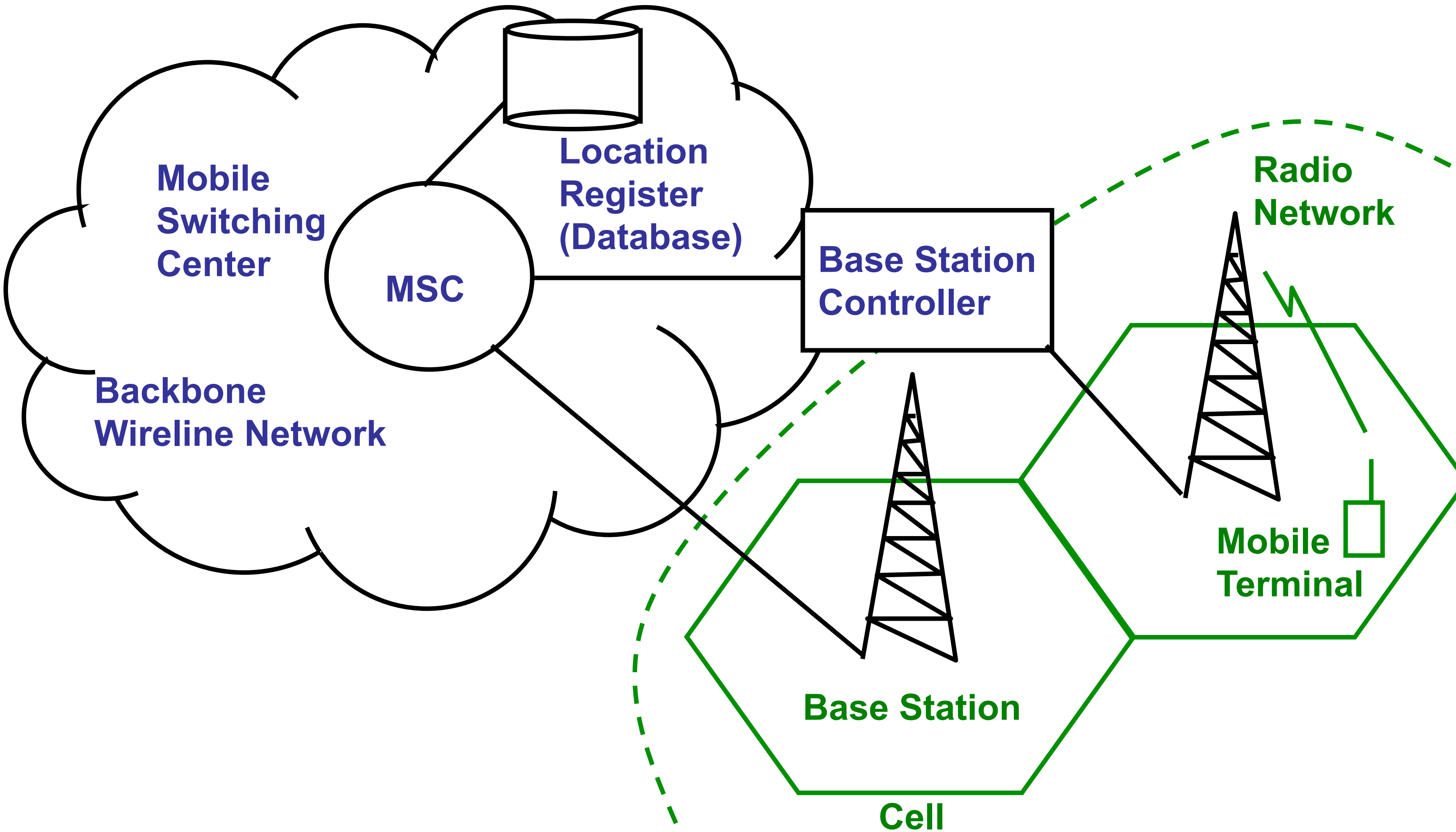
- Mobile data
  - CDPD shares AMPS bands and site infrastructure;
  - GPRS shares GSM's radio system - data rates suitable for Internet
- WLAN – Unlicensed bands, free of charge and rigorous regulations: very attractive!
  - IEEE 802.11 and IEEE 802.11b use DSSS physical layer;
  - HIPERLAN/1 uses GMSK;
  - IEEE 802.11a and HIPERLAN/2 use OFDM: next generation

CDPD – Cellular Digital Packet Data
GPRS – General Packet Radio Service
DSSS – Direct Sequence Spread Spectrum
GMSK – Gaussian Minimum Shift Keying
OFDM – Orthogonal Frequency Division Multiplexing

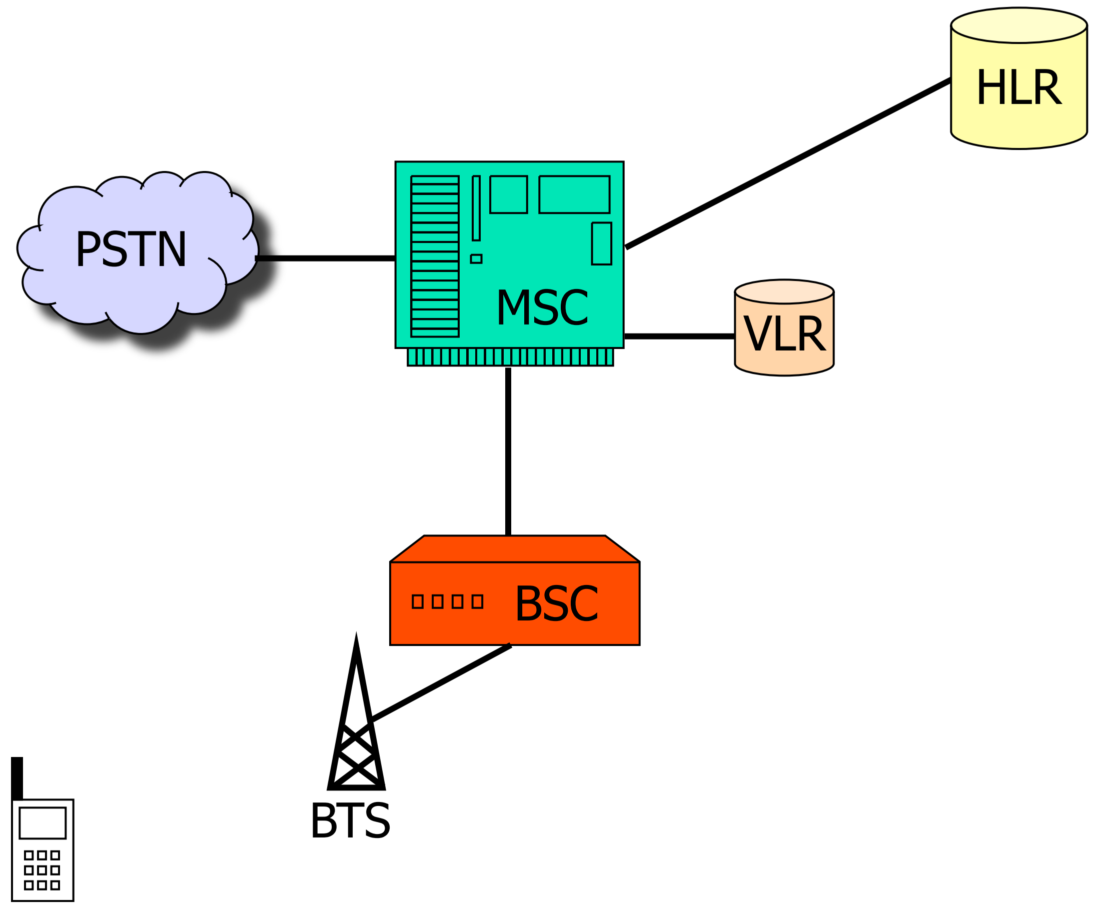
General Wireless Network Infrastructure

- Getting familiar with terms:
  - MS/MT: Mobile Station/Mobile Terminal
  - BS: Base Station
  - MSC: Mobile Switching Center
  - HLR: Home Location Register (database)
  - VLR: Visitor Location Register (database)
- Cellular Network Architecture
- Mobility Management

Cellular Network Architecture

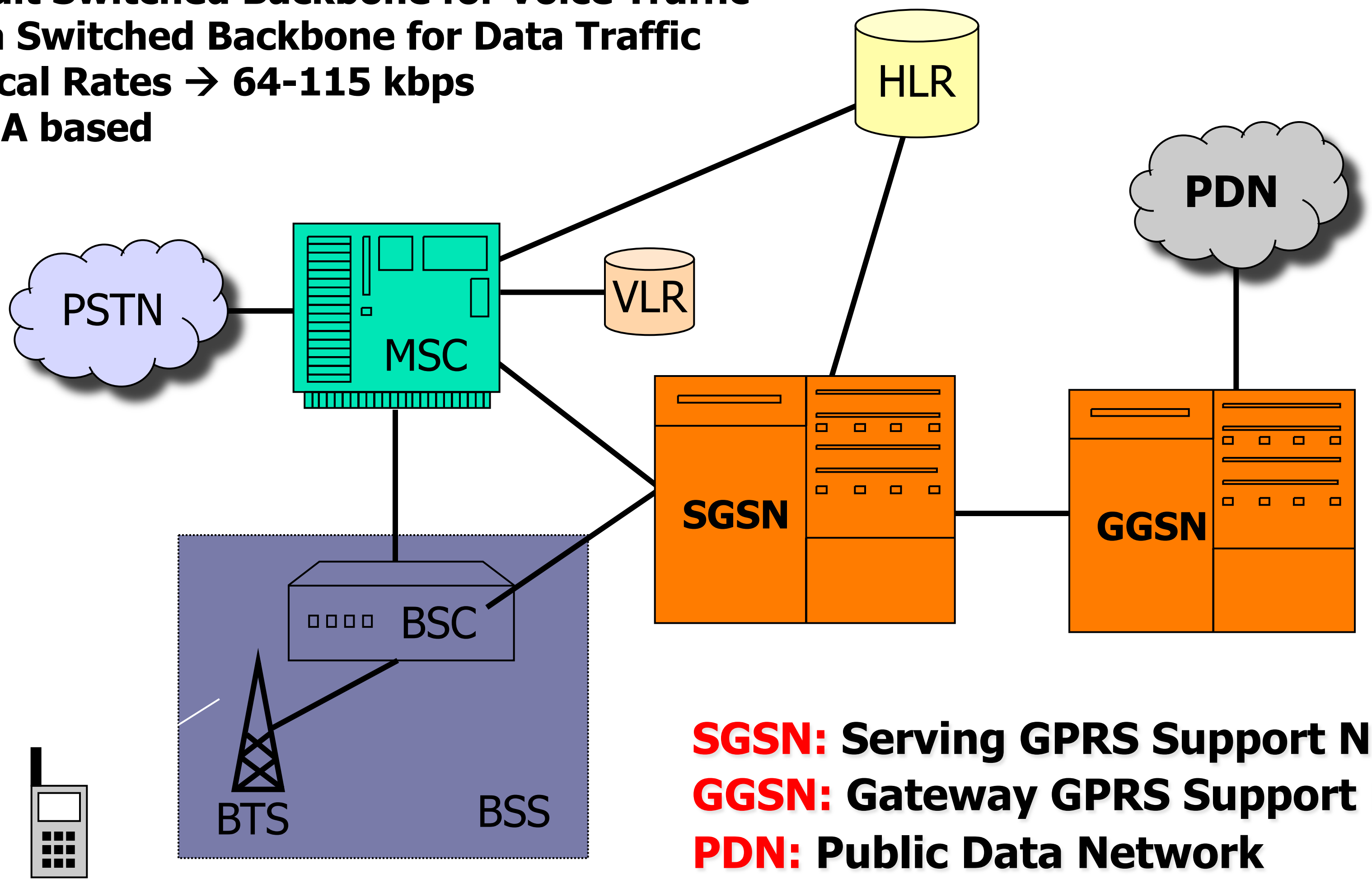


2G Reference Model



2.5G (GPRS) Reference Model

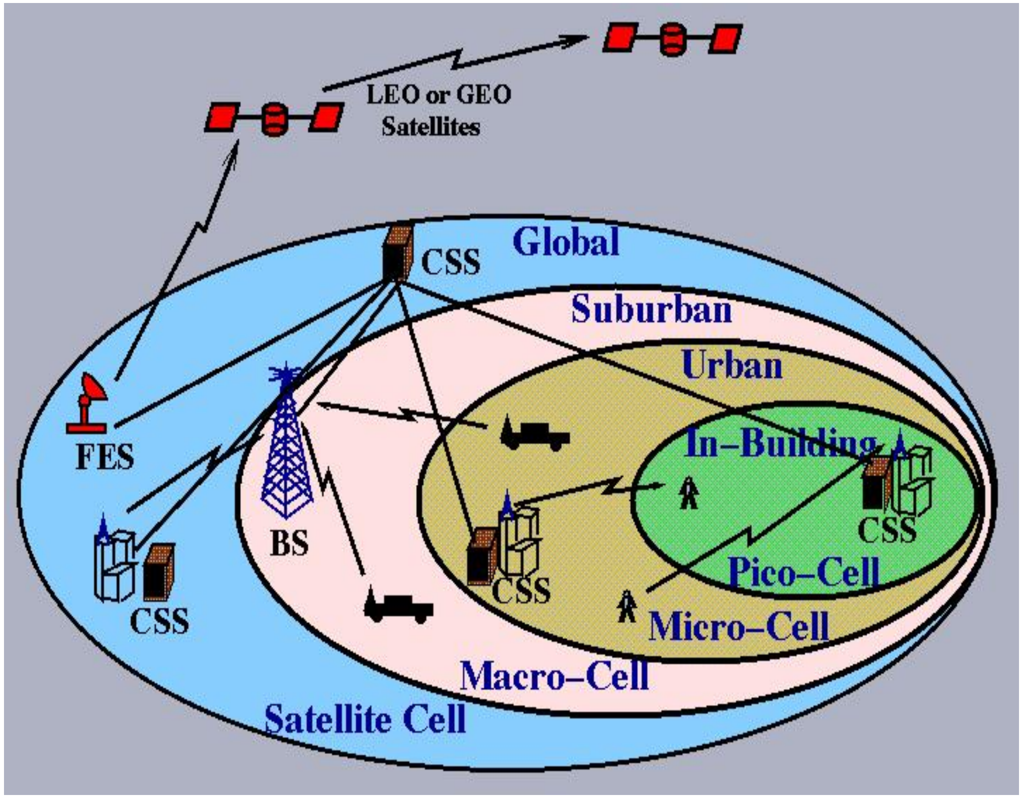
- **Circuit Switched Backbone for Voice Traffic**
- **Data Switched Backbone for Data Traffic**
- **Typical Rates → 64-115 kbps**
- **TDMA based**



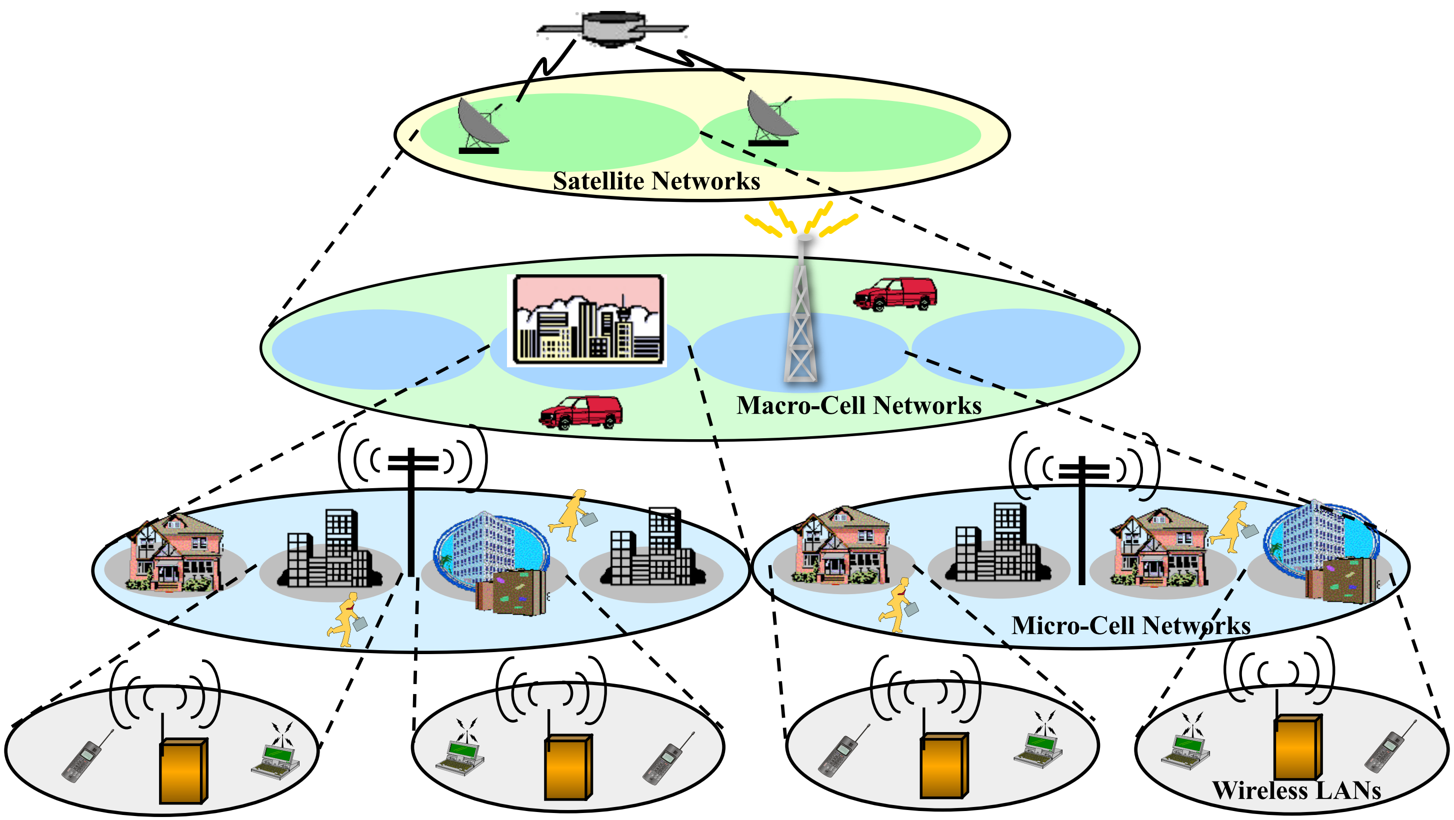
SGSN: Serving GPRS Support Node
GGSN: Gateway GPRS Support Node
PDN: Public Data Network

3G Architecture

- Hierarchical Cell Structure
- Global Roaming
- Radio Spectrum



Heterogeneous Overlay Networks



Heterogeneous networks have fully overlapping areas of coverage and significantly different cell sizes.

3G Standards

- W-CDMA:
  - Developed by the 3G Partnership Project (3GPP)
  - UTRA-TDD and UTRA-FDD
  - Backers → Ericsson, Nokia, NTT DoCoMo, Korea Telecom
- cdma2000:
  - Compatible with IS-95
  - Further developed by the 3G Partnership Project Number 2 (3GPP2)
  - Backers → Qualcomm, Lucent, Motorola, Korea Telecom

Killer Applications for 3G

- Service Position Location and Mapping
- Audio and Video Content
- Application Downloading
- Multimedia Messaging
- Video Conferencing
- Internet Connectivity
- Enterprise Connectivity

Comparison of 2G and 3G Systems

	2G	3G
Digital Technology	Modulation, Speech, Channel Coding	Increased Use also Software Radios
Environments	Vehicular, Pedestrian, FWA	Vehicular, Pedestrian, Office, FWA, Satellite
Frequency Bands	800MHz, 900MHz, 1.5GHz, 1.8GHz	2 GHz
Services	Low/Medium Rates; Primarily Voice, Data	Higher Data Rates; Circuit/Packet Switched and Multimedia Services
Roaming	Restricted	Global Roaming

3G → 4G

3G

- Back compatibility to 2G
- Circuit and packet switched data
- A combination of existing & evolved digital equipment
- Data rate
  - 2Mbps for fixed area
  - 384 kbps for indoor/outdoor and pedestrian
  - 144 kbps for vehicular

4G

- Extend the capacity of 3G by one order of magnitude
- Entirely packet switched networks
- All elements are digital
- Higher bandwidth (~~100Mbps)

What’s New in 4G ?

- Entirely packet-switched networks
- All elements are digital
- Higher bandwidths to provide multimedia services at lower cost (~~ 100Mbit/s)
- High network security (security layer)
- VoIP → the `Killer' Application for 4G
- Motorola VoIP cell phones into the market (2004).

CONCERN:

If the quality of VoIP is not satisfactory, it is meaningless to talk about "all-IP"/4G: there will be still two backbones, one for voice and one for data.

WLANs are promising Wireless Data Networking Architecture

- WLANs (WiFis) may be the hottest way to connect to the Internet these days
- Wireless Internet access cheaper, faster and farther reaching. (early 2005)

Why Choose? A vs B vs G

Wireless Technology Comparison Chart

Wireless Standard	802.11b		802.11a		802.11g	
Popularity		Widely adopted. Readily available everywhere.		New technology.		New technology with rapid growth expected.
Speed	11 Mbps	Up to 11Mbps (note: cable modem service typically averages no more than 4 to 5Mbps).	54 Mbps	Up to 54Mbps (5X greater than 802.11b).	54 Mbps	Up to 54Mbps (5X greater than 802.11b).
Relative Cost	$	Inexpensive.	$$$	Relatively more expensive.	$$	Relatively inexpensive.
Frequency	2.4 GHz	More crowded 2.4GHz band. Some conflict may occur with other 2.4GHz devices like cordless phones, microwave ovens, etc.	5 GHz	Uncrowded 5GHz band can coexist with 2.4 GHz networks without interference.	2.4 GHz	More crowded 2.4GHz band. Some conflict may occur with other 2.4GHz devices like cordless phones, microwave ovens, etc.
Range	100-150	Good Range. Typically up to 100-150 feet indoors, depending on construction, building materials, room layout.	25-75	Shorter range than 802.11b & 802.11g. Typically 25 to 75 feet indoors.	100-150	Good Range. Typically up to 100-150 feet indoors, depending on construction, building materials, room layout.
Public Access		The number of public "hotspots" is growing rapidly, allowing wireless connectivity in many airports, hotels, college campuses, public areas, and restaurants.	X	None at this time.		Compatible with current 802.11b hotspots (at 11Mbps). Also, it is expected that most 802.11b hotspots will quickly convert to 802.11g.
Compatibility	OK 802.11b	Widest adoption.	OK 802.11a	Incompatible with 802.11b or 802.11g.	OK 802.11b 802.11g	Interoperates with 802.11b networks (at 11Mpbs). Incompatible with 802.11a.

Complementary Nature of 3G and WLANs

Wi-Fi technology alone does not offer the mobile or wide area connectivity required for network access on a moving bus, train, or subway

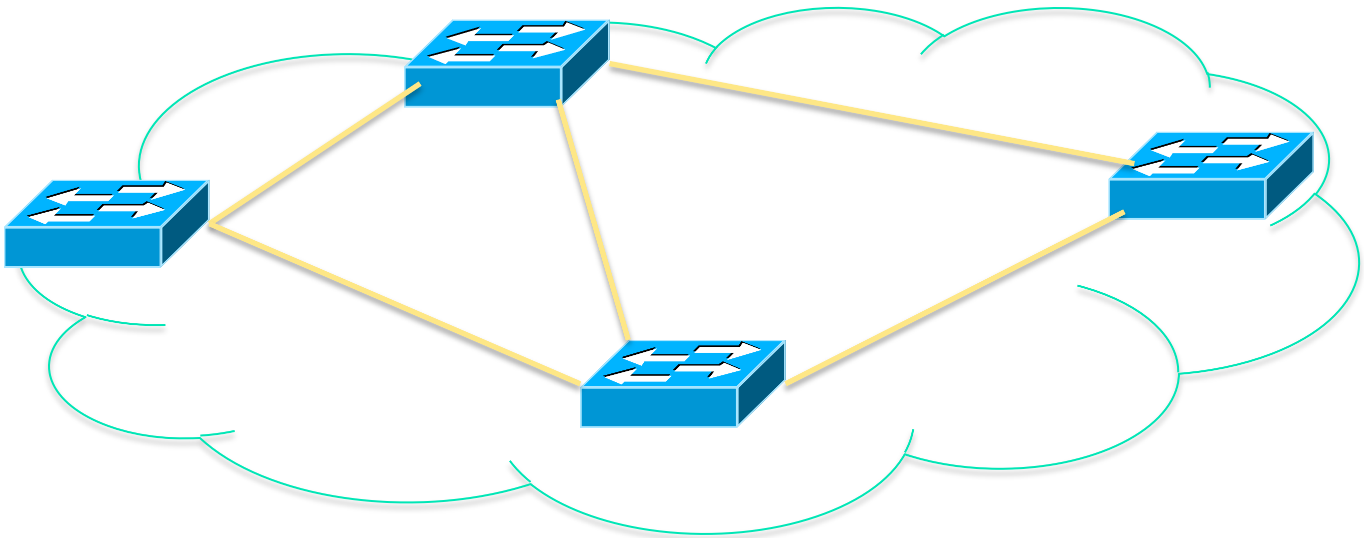
3G	WLAN
Low data rate	High data rate
High cost	Low cost
High mobility	Low mobility
Ubiquitous coverage	Limited coverage

→ *Integration is promising !!*

Challenges ahead of 3G and WLAN Integration

- Architecture to integrate 3G and WLAN
- Mobility management (seamless roaming) in the 3G/WLAN between different service providers
- Authentication and security in the integrated architecture
- Regulatory requirements
- Billing
- Mapping of services between 3G and WLAN
- Scalability

Traditional Computer Networks

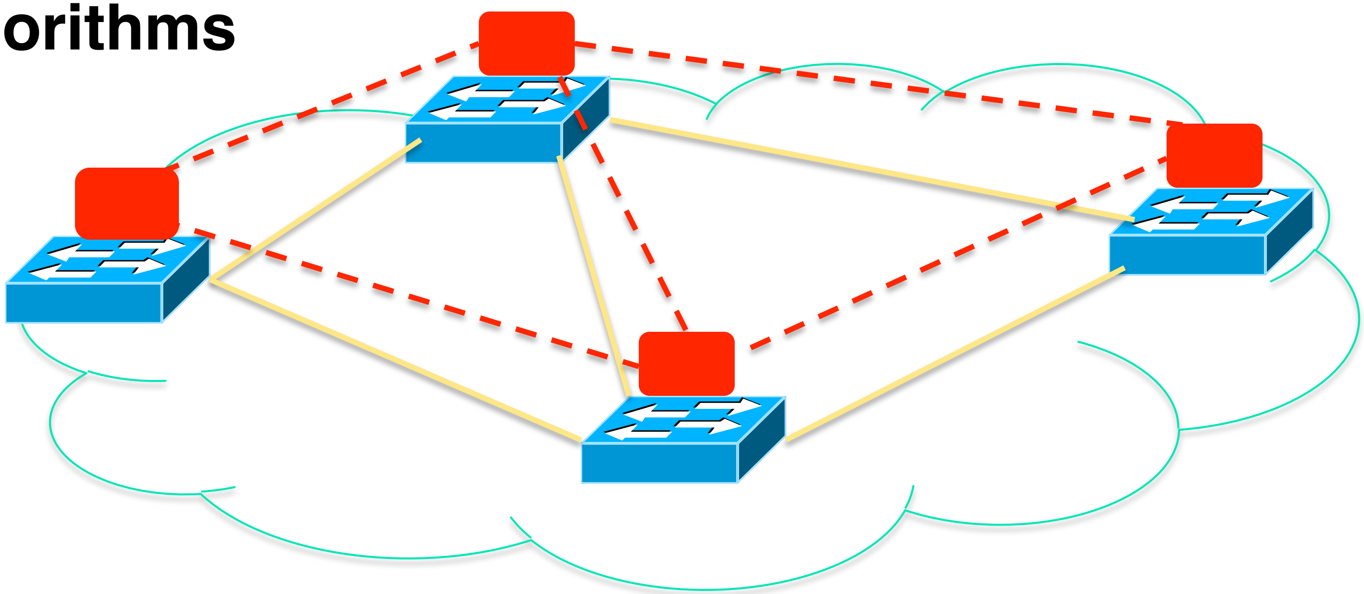


Data plane:
Packet streaming

Forward, filter, buffer, mark, rate-limit, and measure packets

Traditional Computer Networks

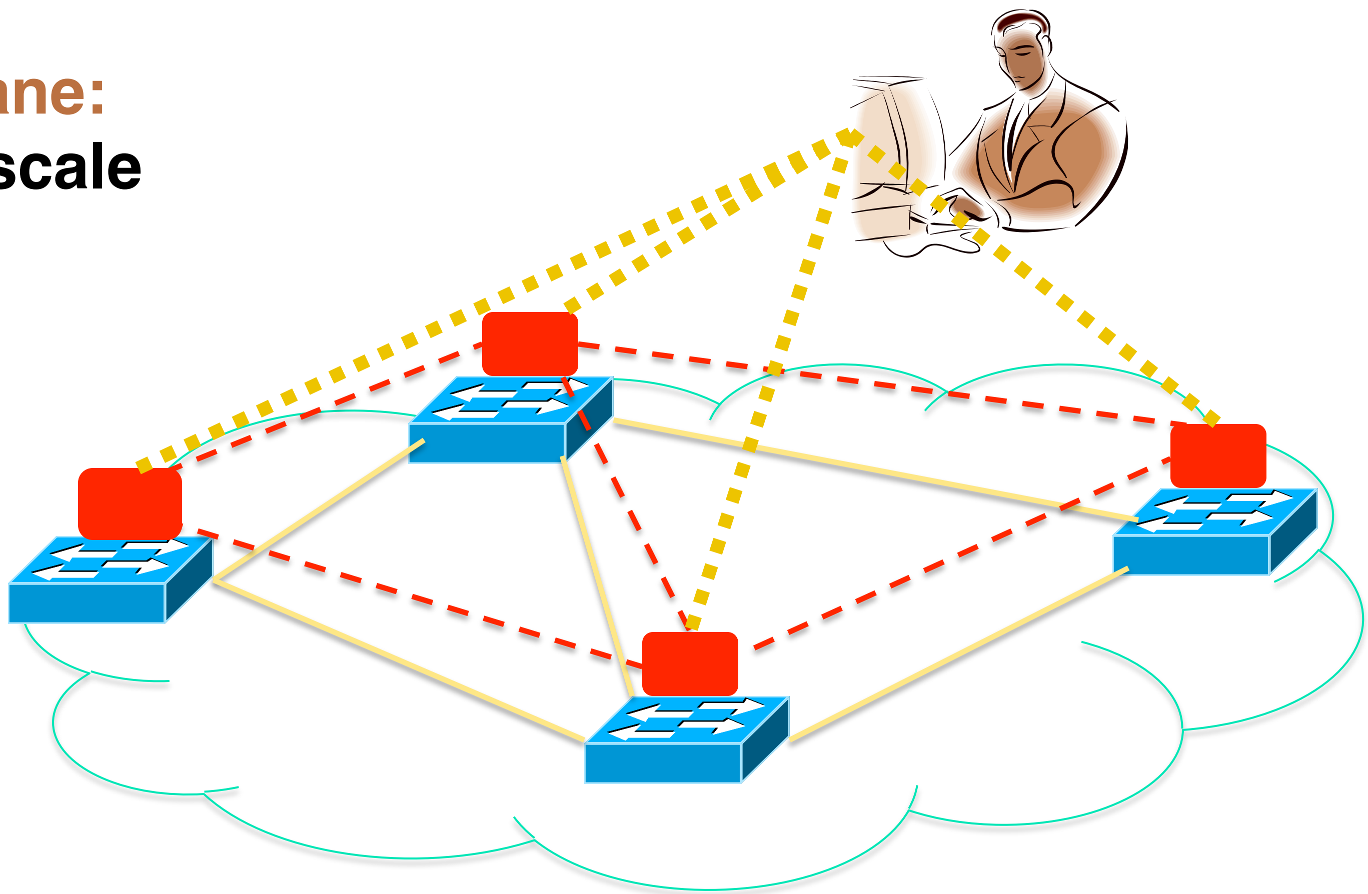
Control plane:
Distributed algorithms



Track topology changes, compute routes, install forwarding rules

Traditional Computer Networks

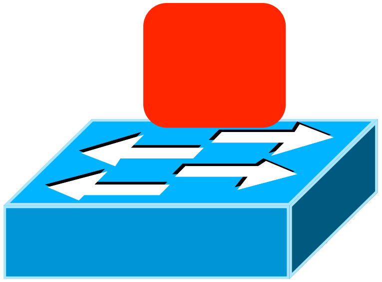
Management plane:
Human time scale



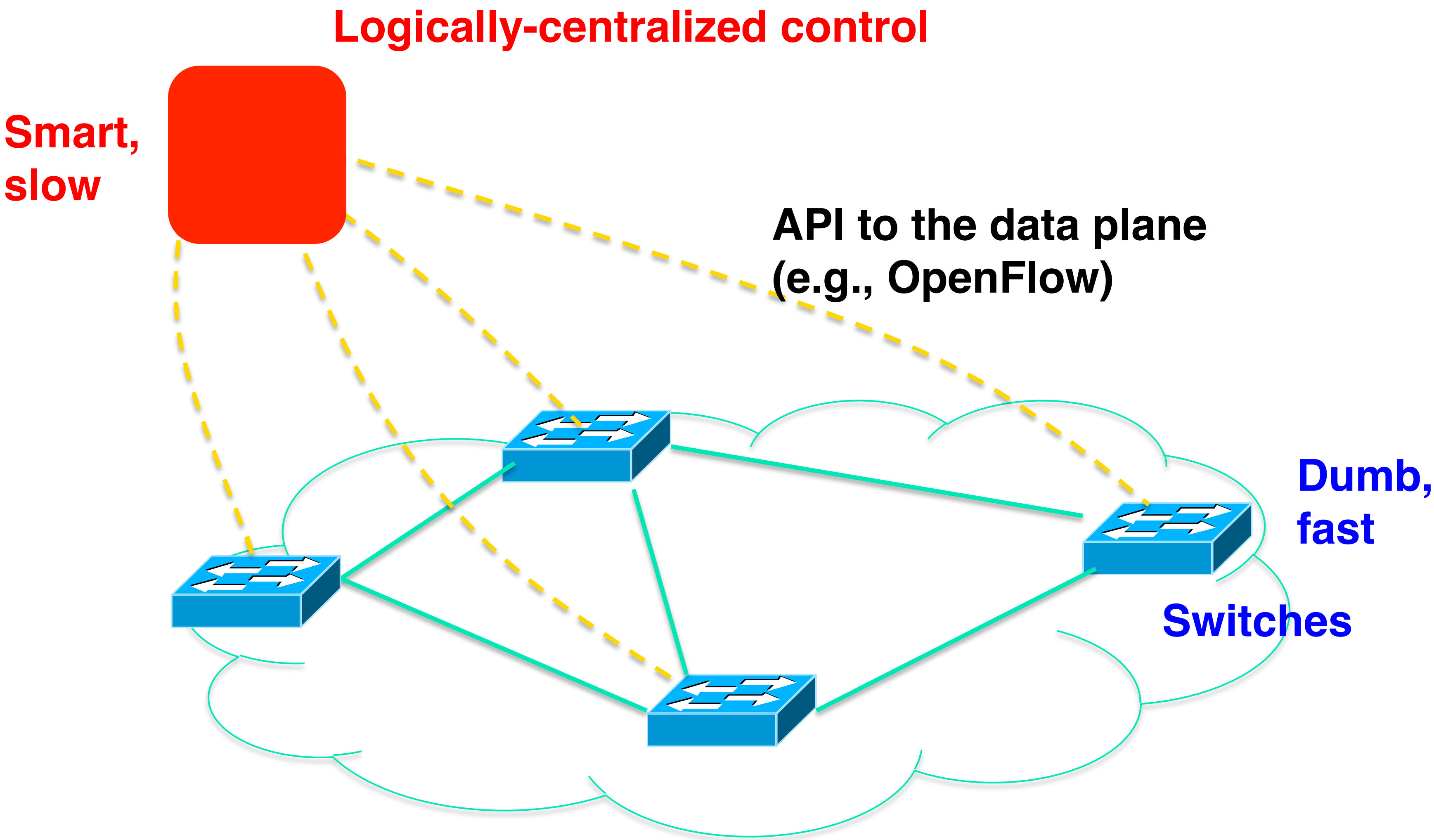
Collect measurements and configure the equipment

Death to the Control Plane!

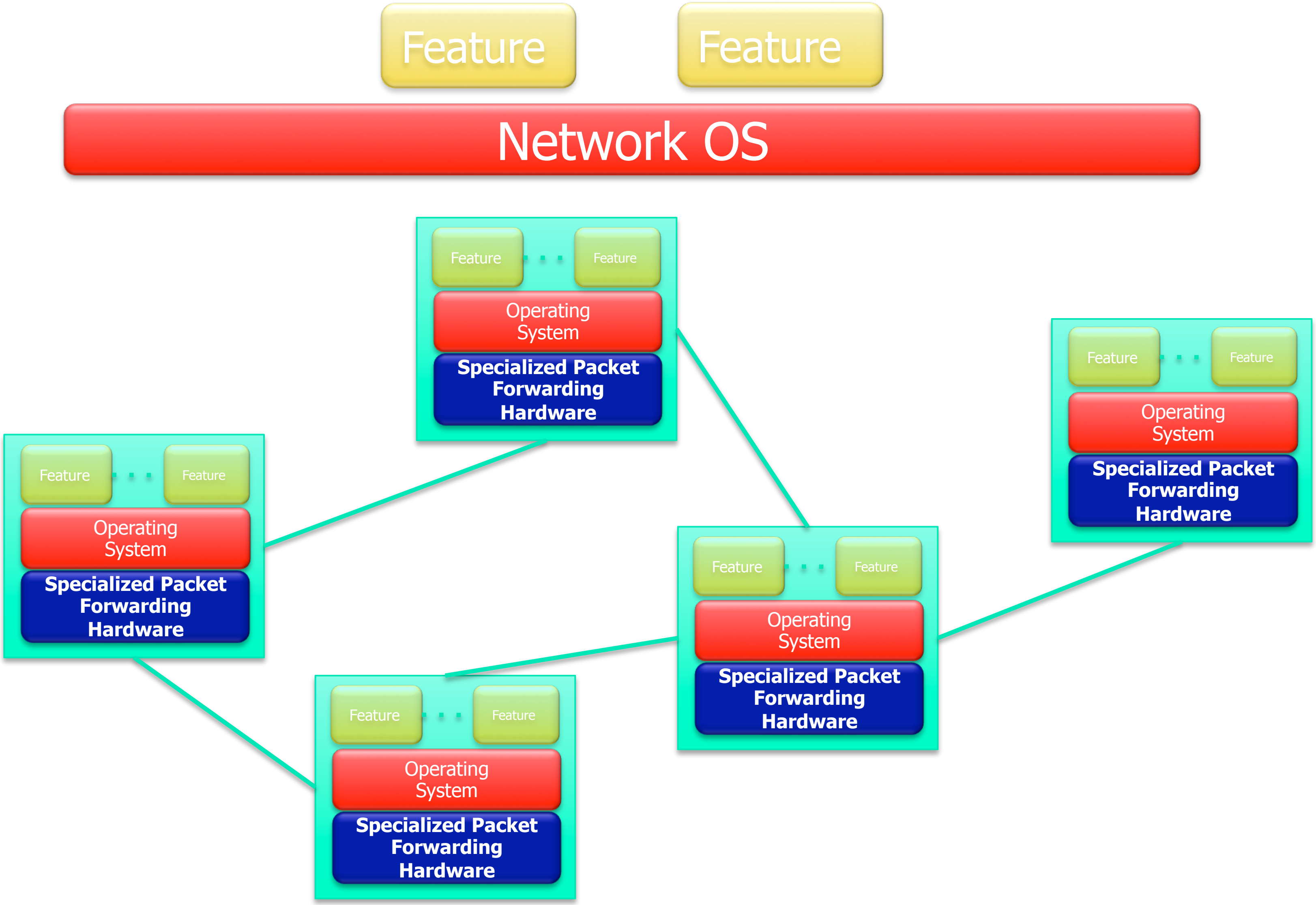
- Simpler management
  - No need to “invert” control-plane operations
- Faster pace of innovation
  - Less dependence on vendors and standards
- Easier interoperability
  - Compatibility only in “wire” protocols
- Simpler, cheaper equipment
  - Minimal software



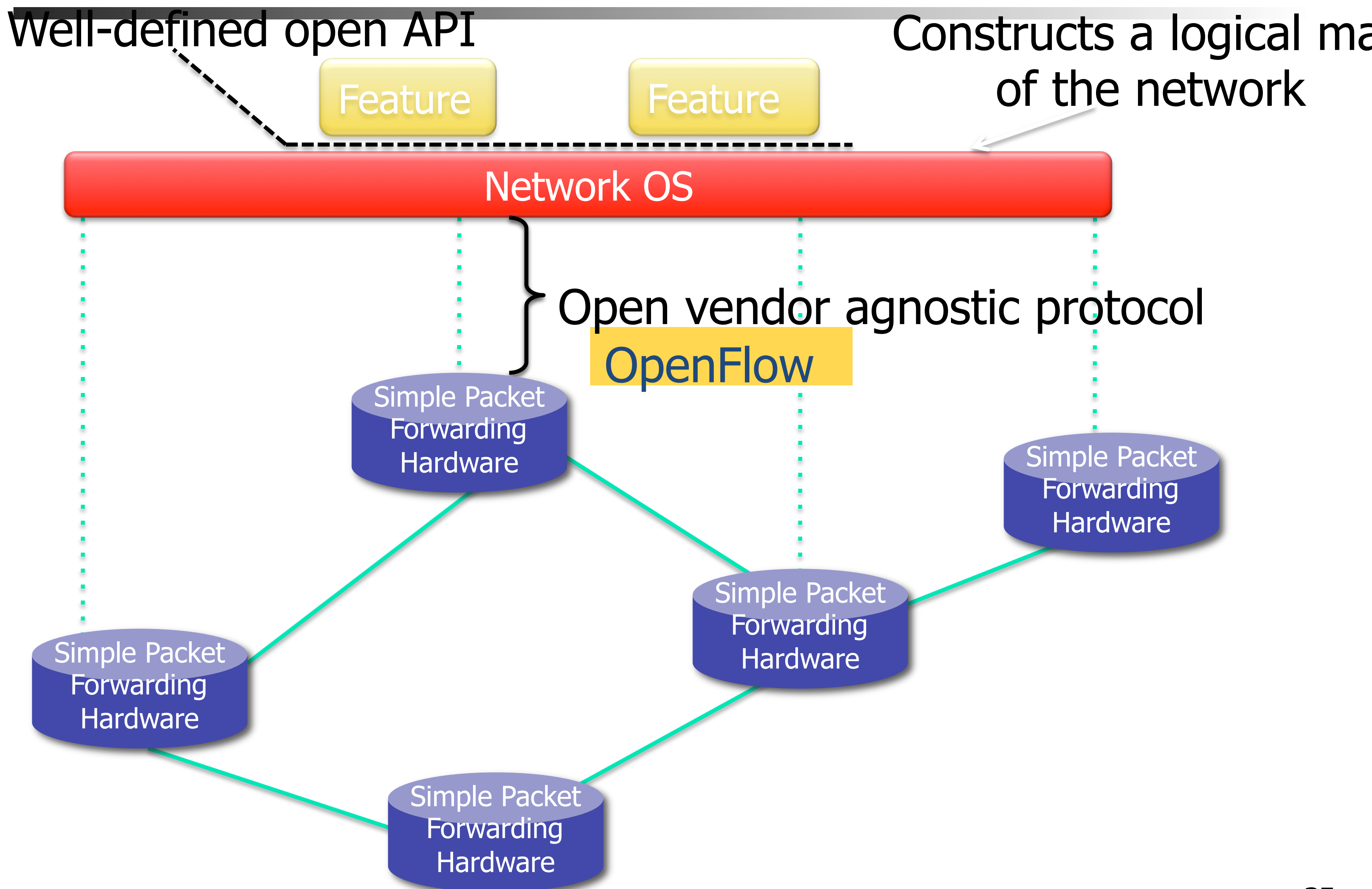
Software Defined Networking (SDN)



From Vertically Integrated to …

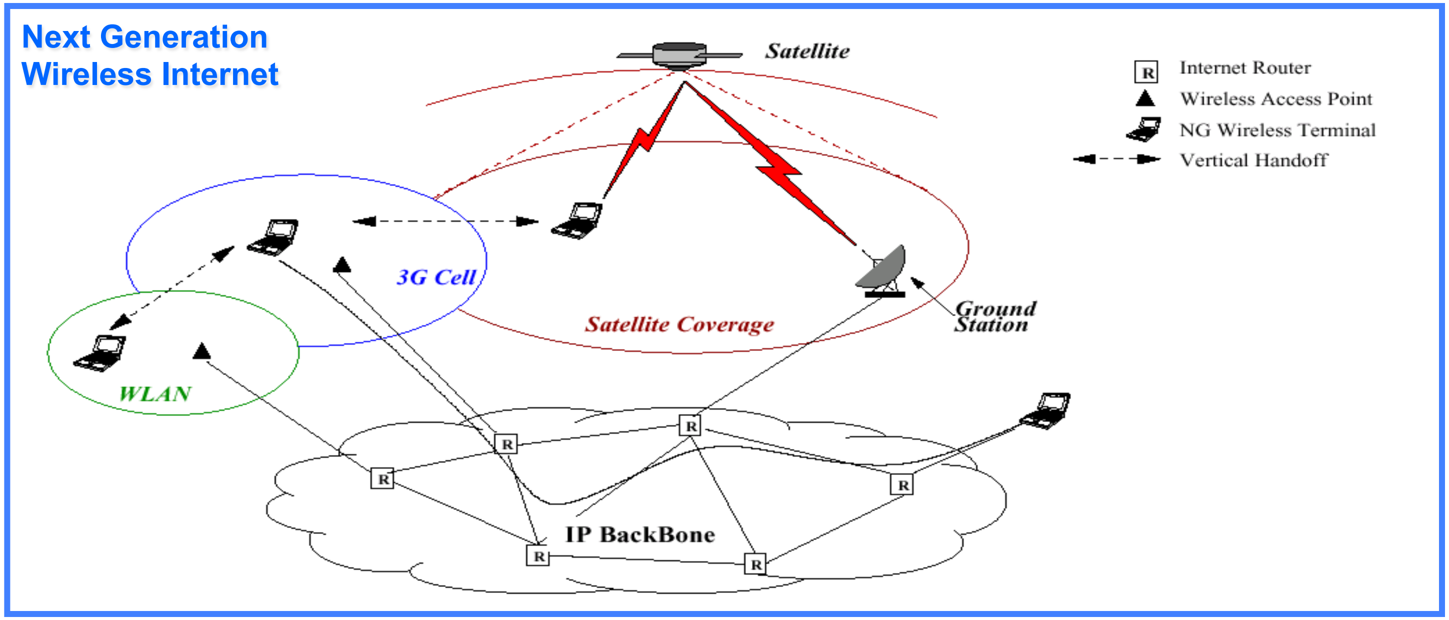


Software Defined Network



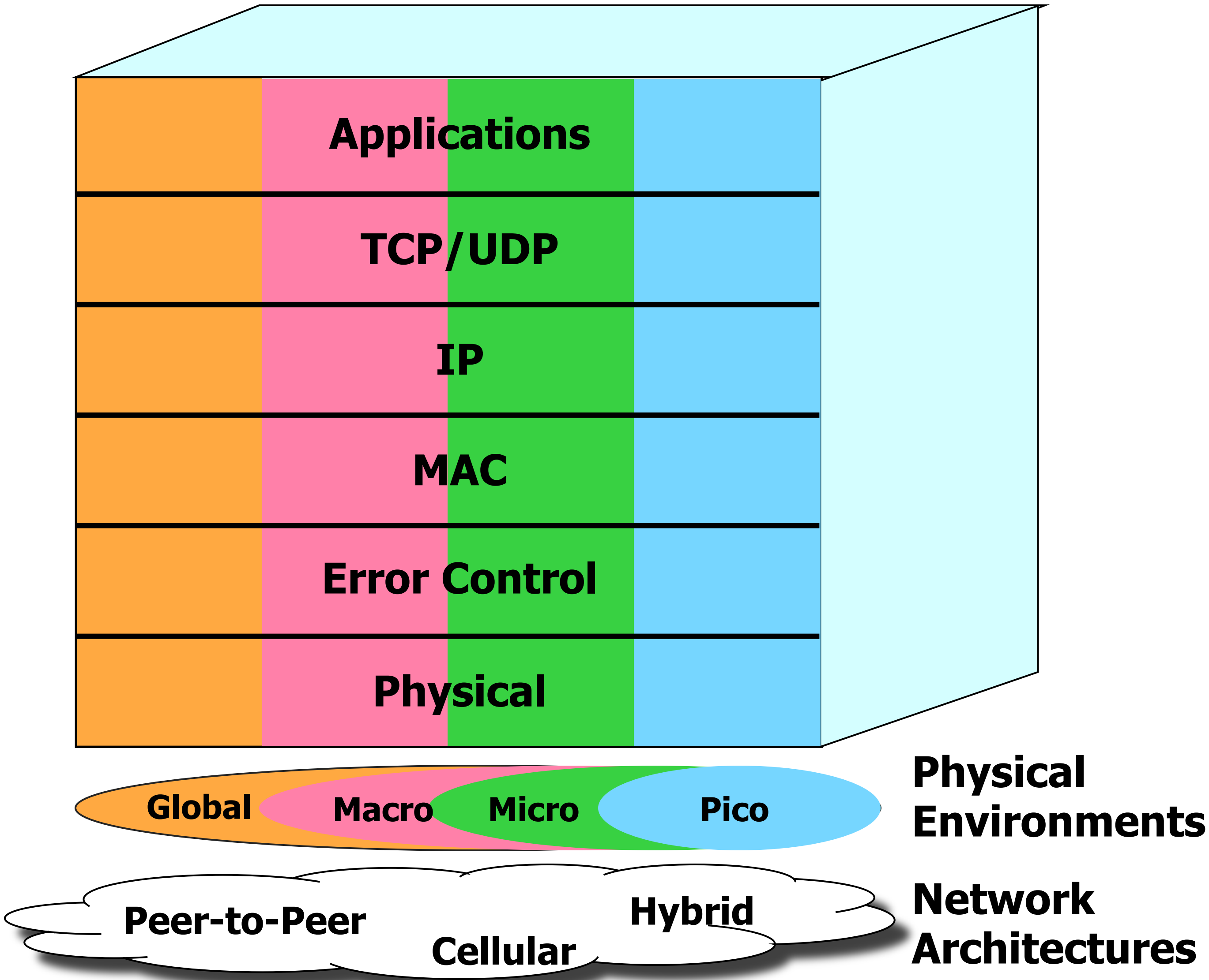
Next Generation Wireless Internet

I.F. Akyildiz, Y. Altunbasak, F. Fekri, R. Sivakumar, "AdaptNET: Adaptive Protocol Suite For Next Generation Wireless Internet," IEEE Communications Magazine, March 2004.

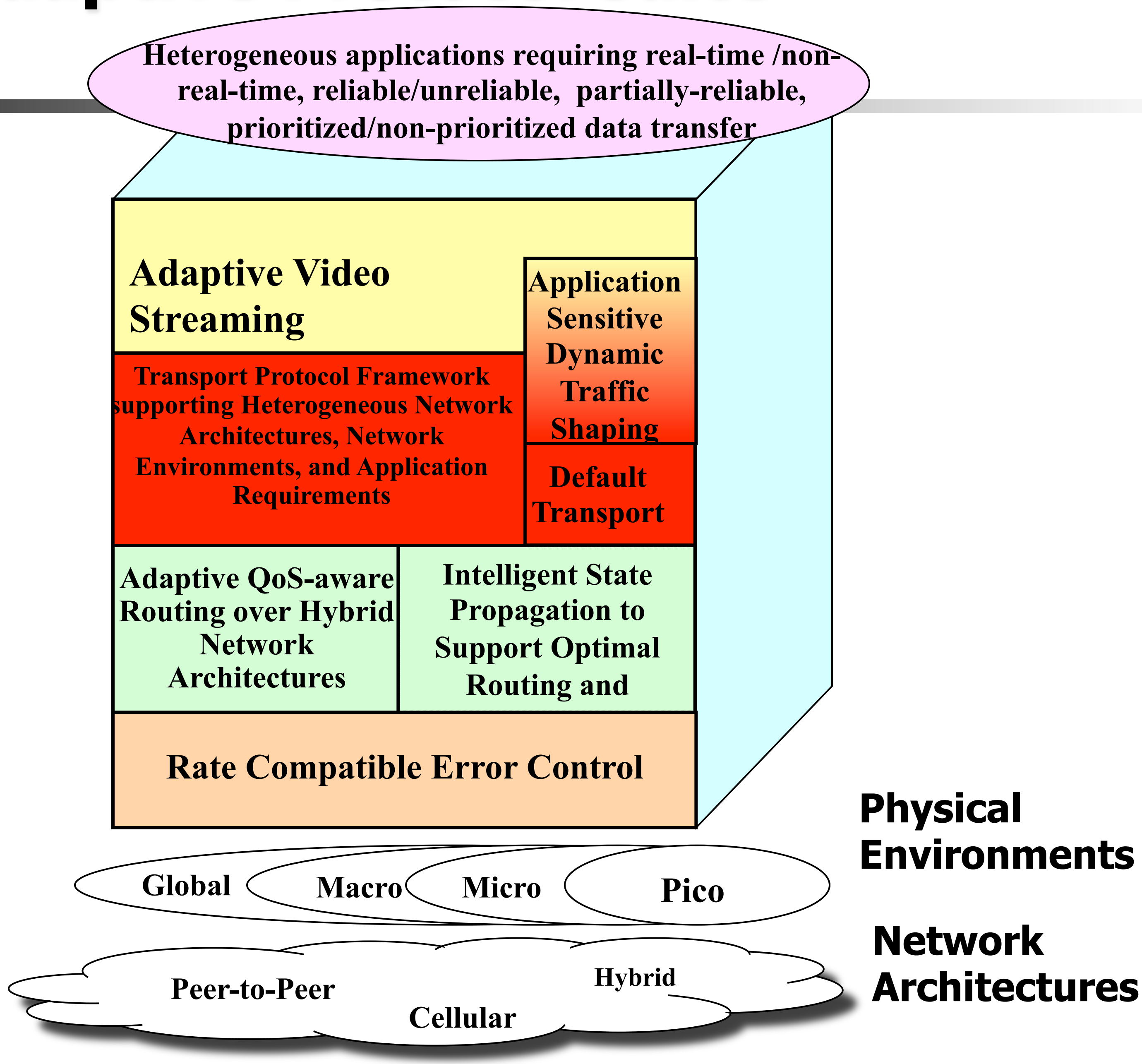


- Convergence of heterogeneous wireless systems
  - WLAN, 2G/3G Systems, Satellite Networks
- IP-based Infrastructure
- Anytime/anywhere high data rate & multimedia

Current Protocol Suite

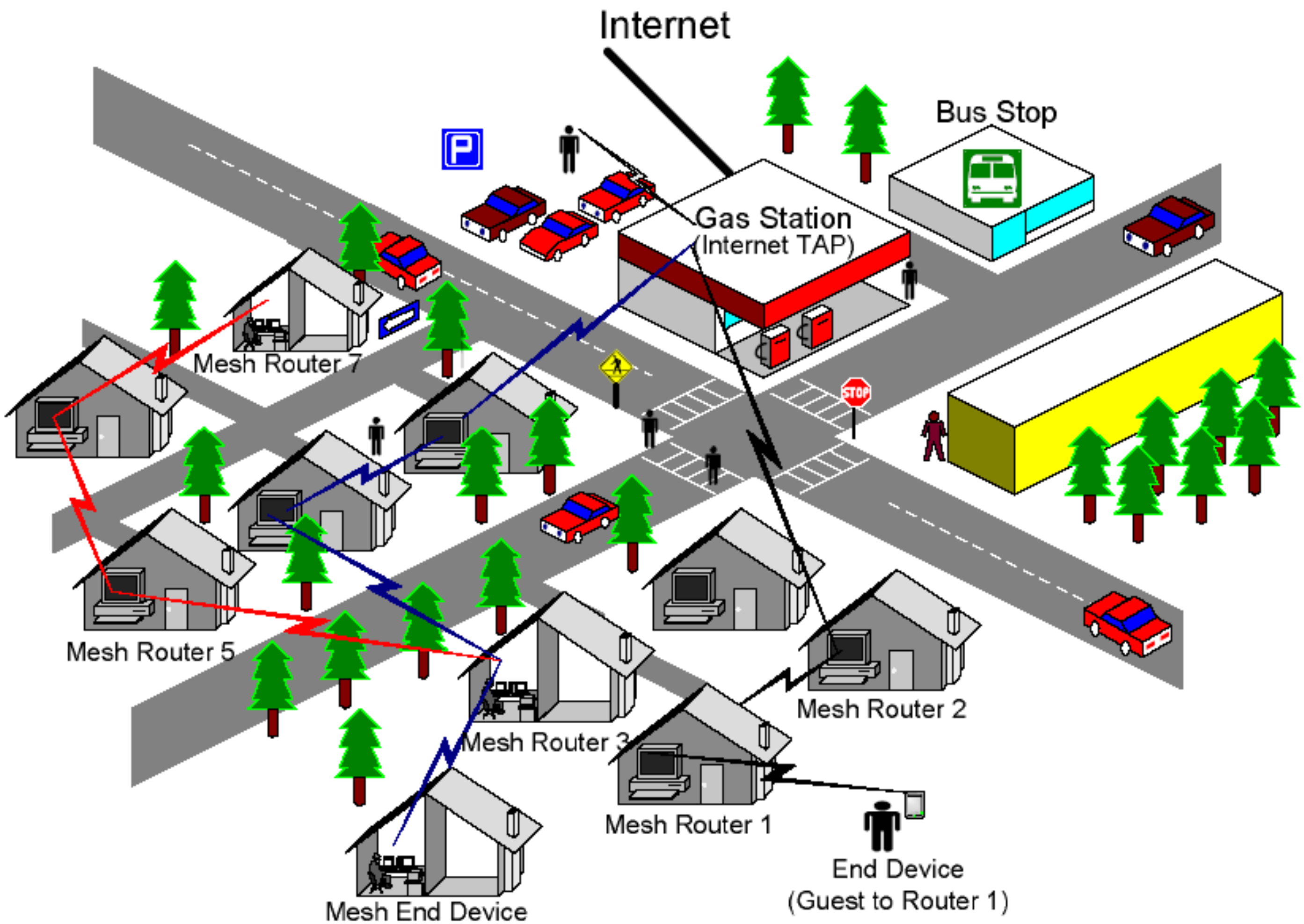


Adaptive Protocol suite



Wireless Mesh Networks

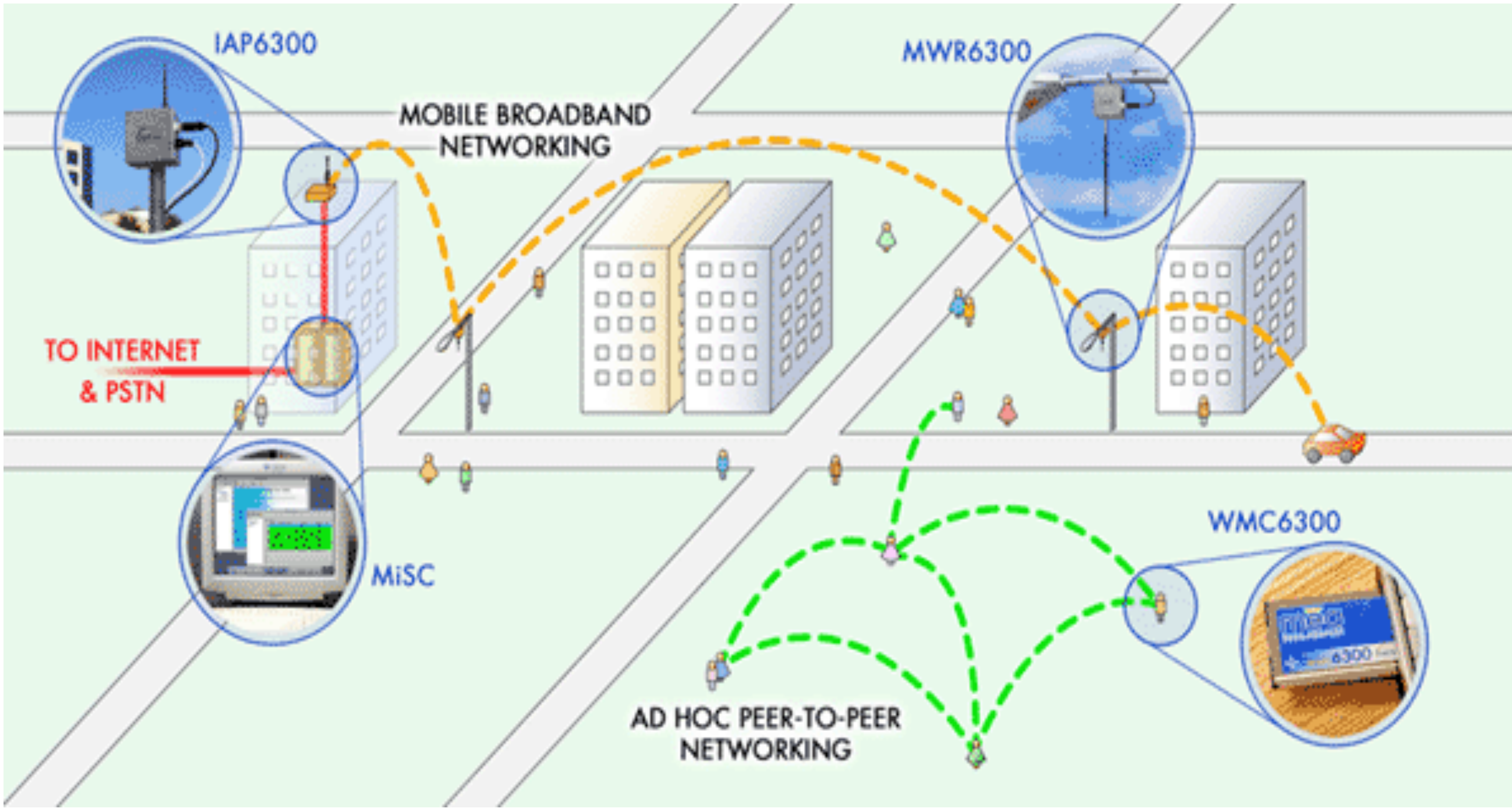
I.F.Akyildiz, X. Wang, W. Wang, "Wireless Mesh Networks: A Survey", Computer Networks (Elsevier) Journal, March 2005.



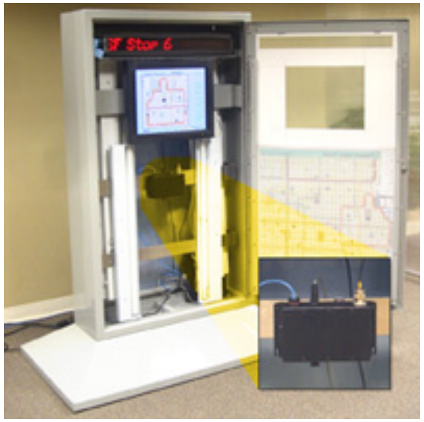
Wireless Mesh Networks

- Extend the range and link robustness of existing Wi-Fi's by allowing mesh-style multi-hopping
- A user finds a nearby user and hops through it - or possibly multiple users - to get to the destination
- Every user becomes a relay point or router for network traffic
- Mesh networks consist of multiple wireless devices equipped with COTS802.11a/b/g cards that work in ad-hoc fashion
- 802.11 capable antennas placed on rooftops allow a large area coverage

Wireless Mesh Networks



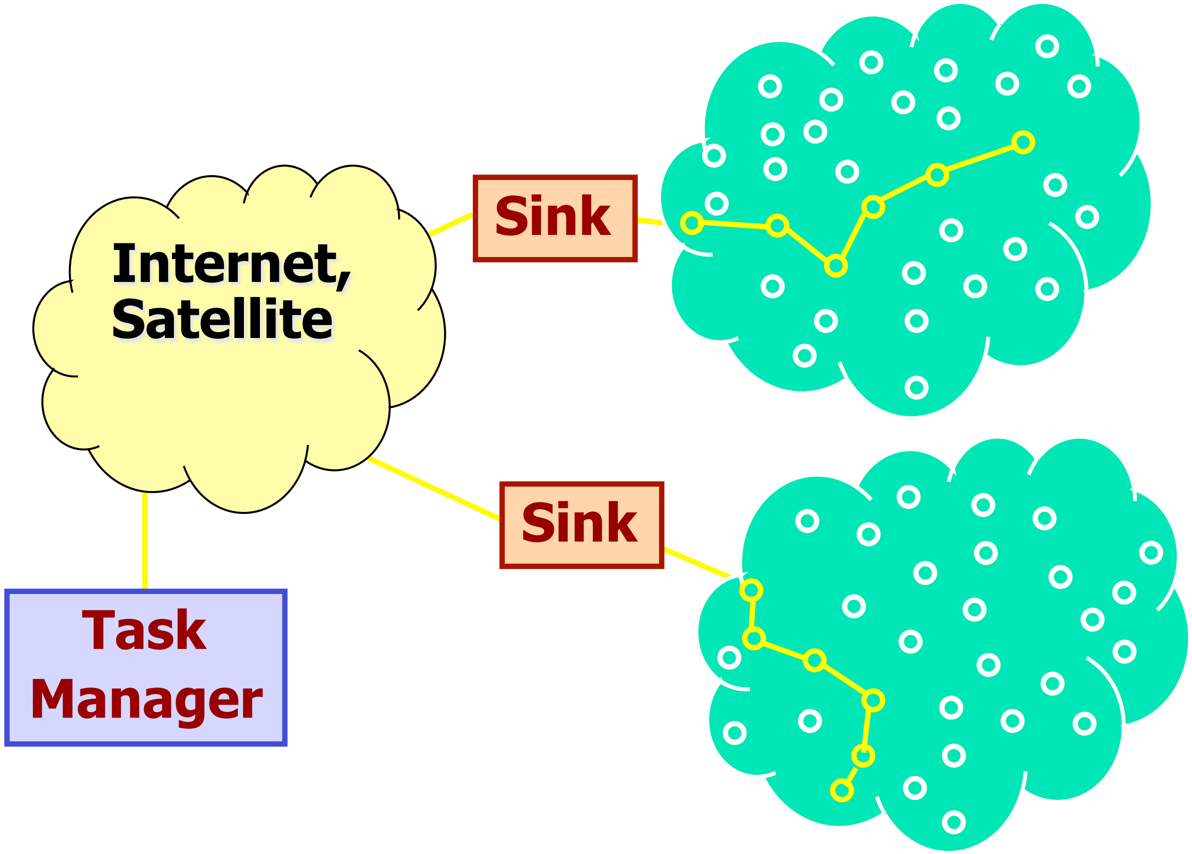
Wireless Mesh Networks



WiMAX: New Broadband Last Mile

- WiMAX an evolving standard for point-to-multipoint wireless networking
- Wi-Fi → for the last one hundred feet (300 ft)
- WiMAX (Worldwide Interoperability for Microwave Access) → for the last mile (30 miles)
  - Ideal for the "last-mile" problem that plagues many neighborhoods that are too remote to receive Internet access via cable or DSL.
  - In areas with cable or DSL access, WiMAX will provide consumers with an additional — and possibly cheaper — alternative
- WiMAX is the commercialization of the maturing IEEE 802.16 standard.
- Uplink and the downlink up to 75 Mbps
- Intel plans to create chipsets that can handle both the 802.11 and 802.16 technologies

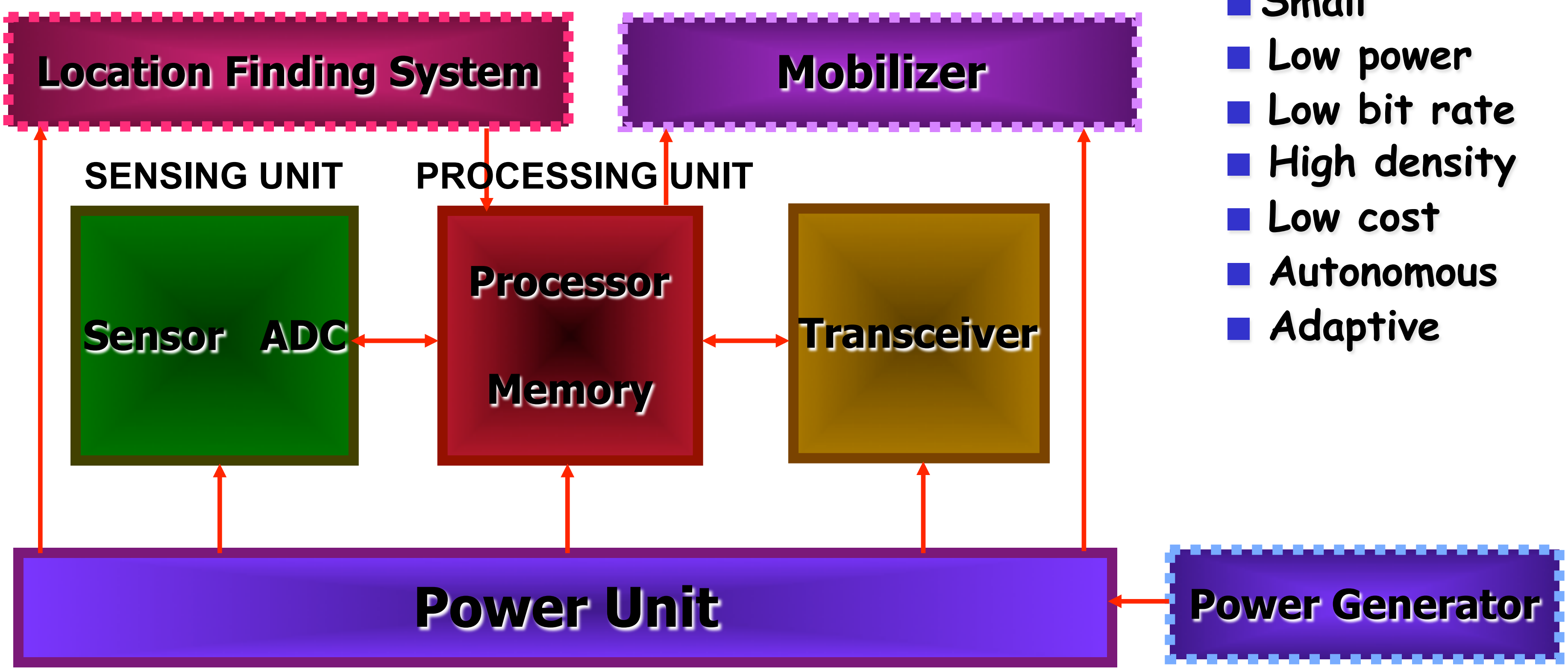
Sensor Networks



- Several thousand nodes
- Nodes are tens of feet of each other
- Densities as high as 20 nodes/m3

I.F.Akyildiz, W.Su, Y. Sankarasubramaniam, E. Cayirci,
"Wireless Sensor Networks: A Survey", *Computer Networks (Elsevier) Journal*, March 2002.
I.F.Akyildiz, M.C.Vuran, O.B.Akan, W.Su,
"Wireless Sensor Networks: A Survey Revisited", *to appear in Computer Networks (Elsevier) Journal*, June 2005.

Sensor Node Hardware



- Small
- Low power
- Low bit rate
- High density
- Low cost
- Autonomous
- Adaptive

Sensor Networks Features

- APPLICATIONS:
  Military, Environmental, Health, Home, Space Exploration, Chemical Processing, Disaster Relief….

- SENSOR TYPES:
  Seismic, Low Sampling Rate Magnetic, Thermal, Visual, Infrared, Acoustic, Radar…

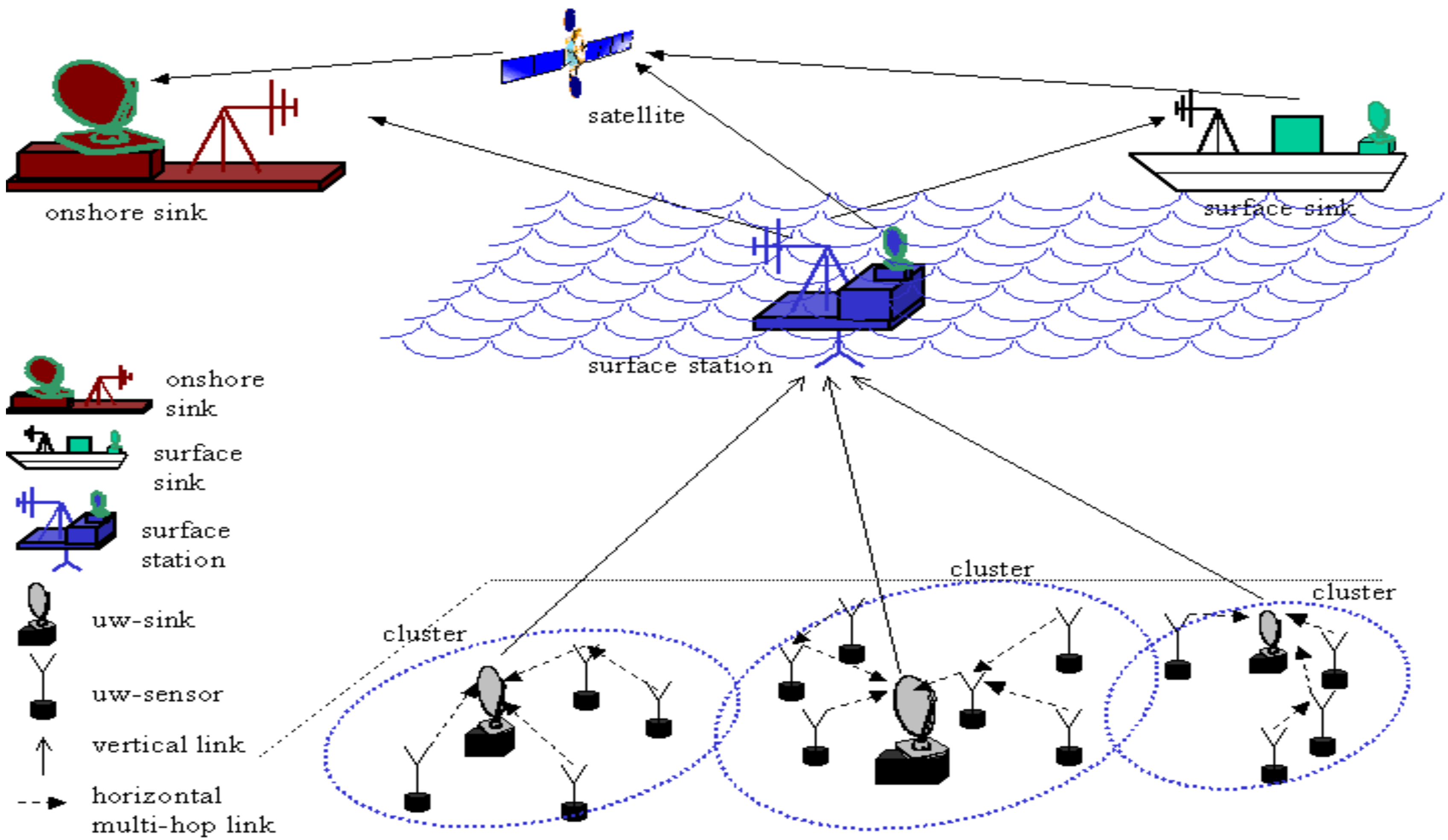
- SENSOR TASKS:
  Temperature, Humidity, Vehicular Movement, Lightning Condition, Pressure, Soil Makeup, Noise Levels, Presence or Absence of Certain Types of Objects, Mechanical Stress Levels on Attached Objects, Current Characteristics (Speed, Direction, Size) of an Object ….

Underwater Acoustic Sensor Networks

I. F. Akyildiz, D. Pompili, T. Melodia,

"Underwater Acoustic Sensor Networks: Research Challenges,"

Ad Hoc Networks Journal, (Elsevier), March 2005.



2D ARCHITECTURE

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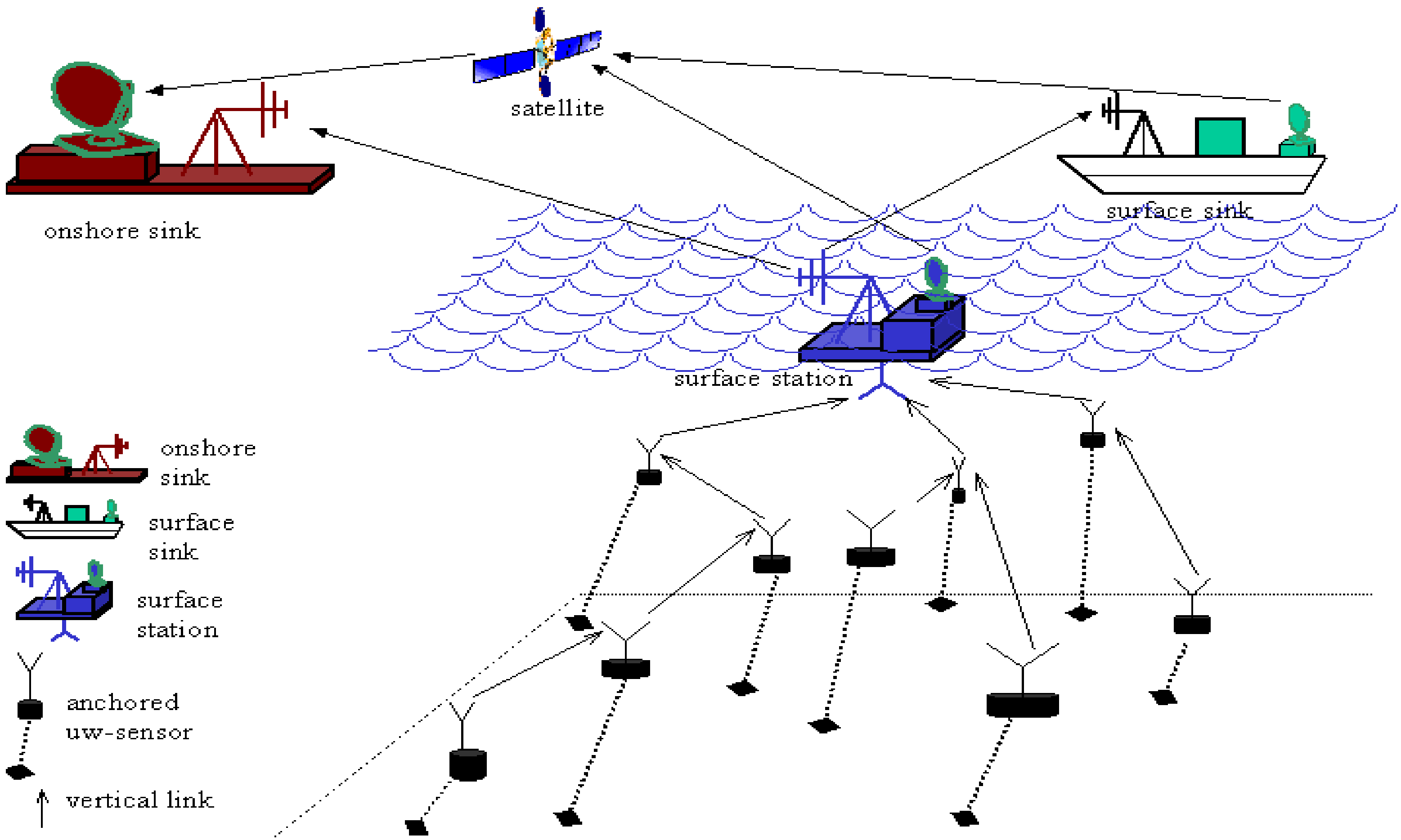


3D ARCHITECTURE

UWSN Applications

- Ocean Sampling Networks
- Pollution Monitoring and other environmental monitoring (chemical, biological, etc.).
- Disaster Prevention
- Assisted Navigation
- Distributed Tactical Surveillance
- Mine Reconnaissance

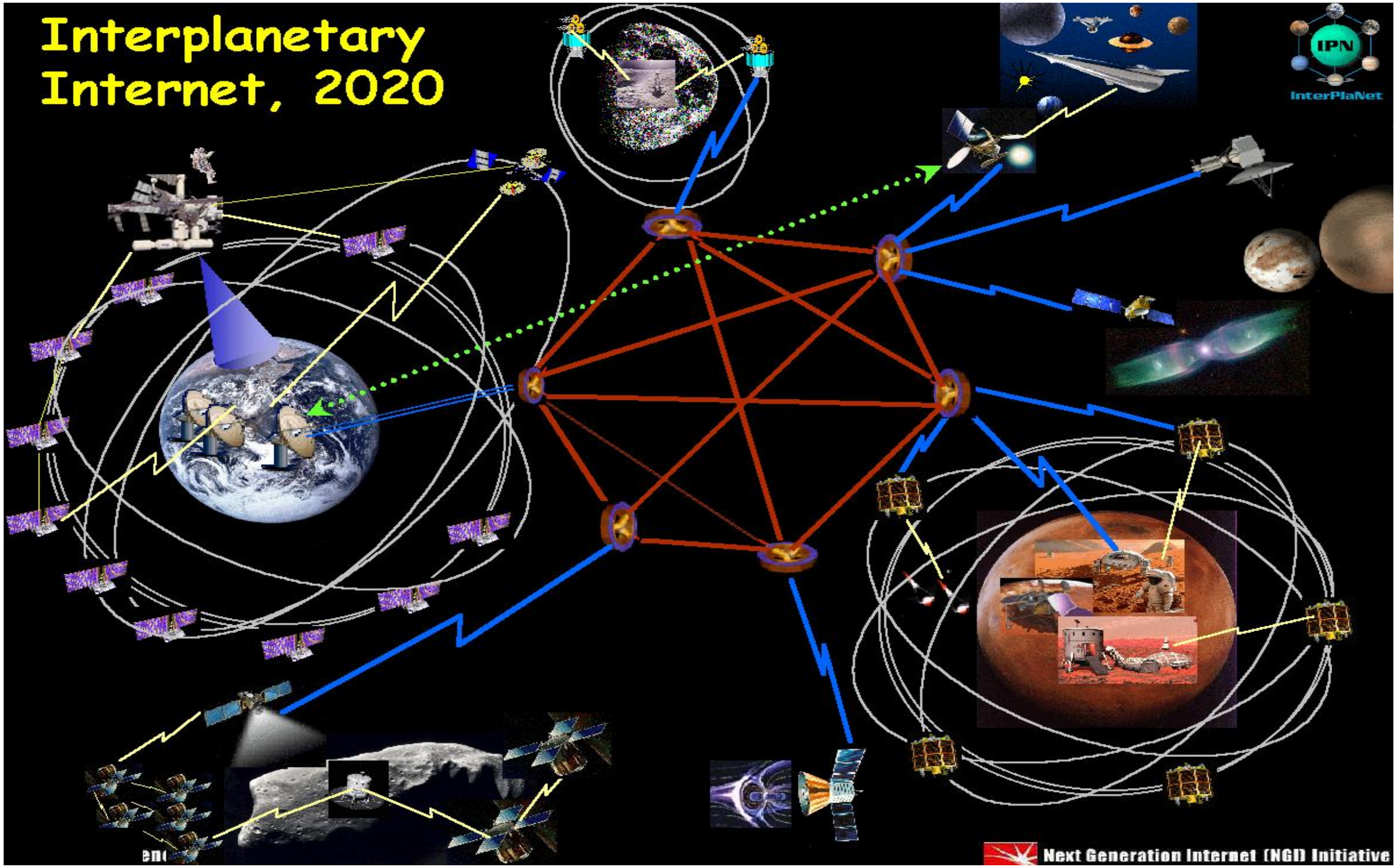
Challenges in the Design of Underwater Sensor Networks

- Battery power is limited and usually batteries can not be recharged
- The available bandwidth is severely limited
- Channel characteristics, which include long and variable propagation delays, multi-path and fading problems
- High bit error rates
- Underwater sensors are prone to failures because of fouling, corrosion, etc.

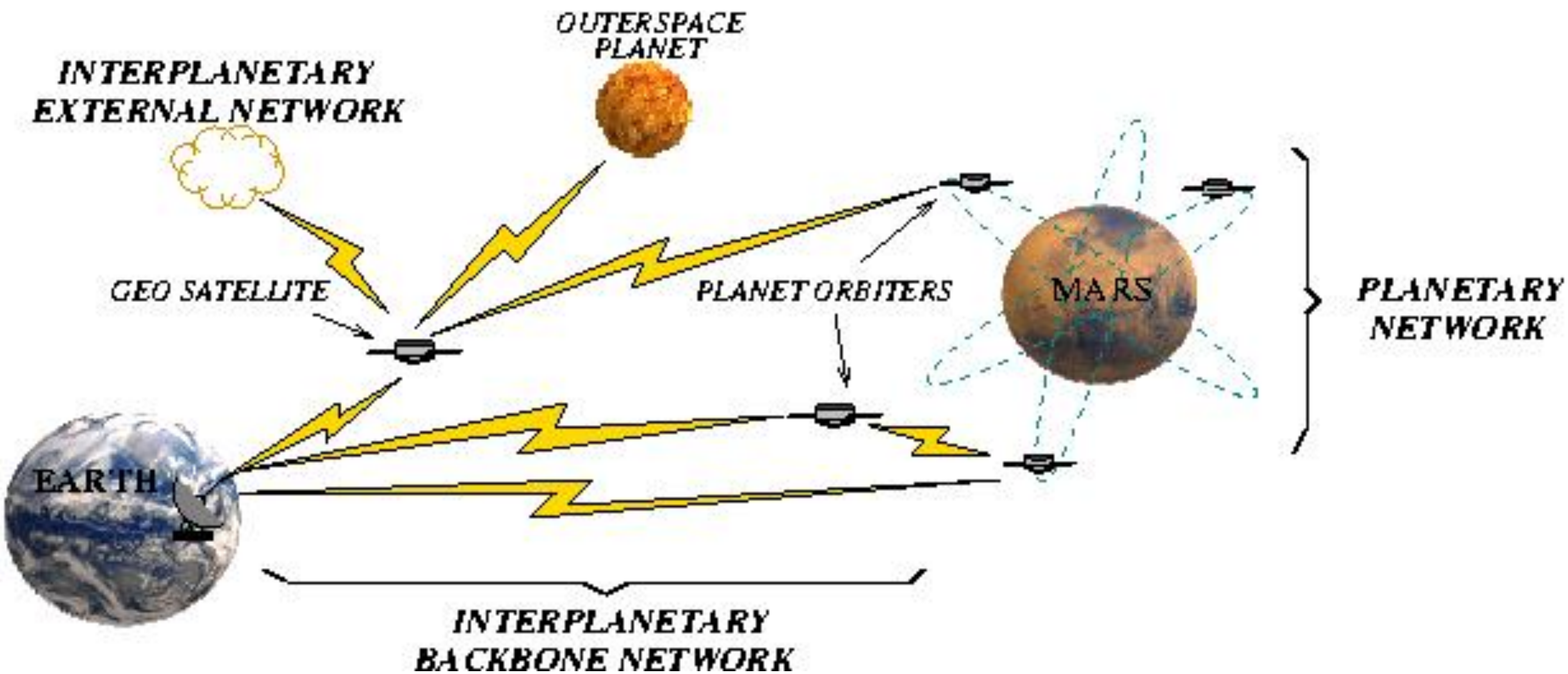
FAR FUTURE WIRELESS NETWORKING

I.F. Akyildiz, O. B. Akan, C. Chen, J. Fang, W. Su
"InterPlaNetary Internet: State-of-the-Art and Research Challenges," *Computer Networks Journal*, Oct. 2003; Shorter version in *IEEE Communications Magazine*, July 2004.

InterPlanetary Internet
Deep Space Network

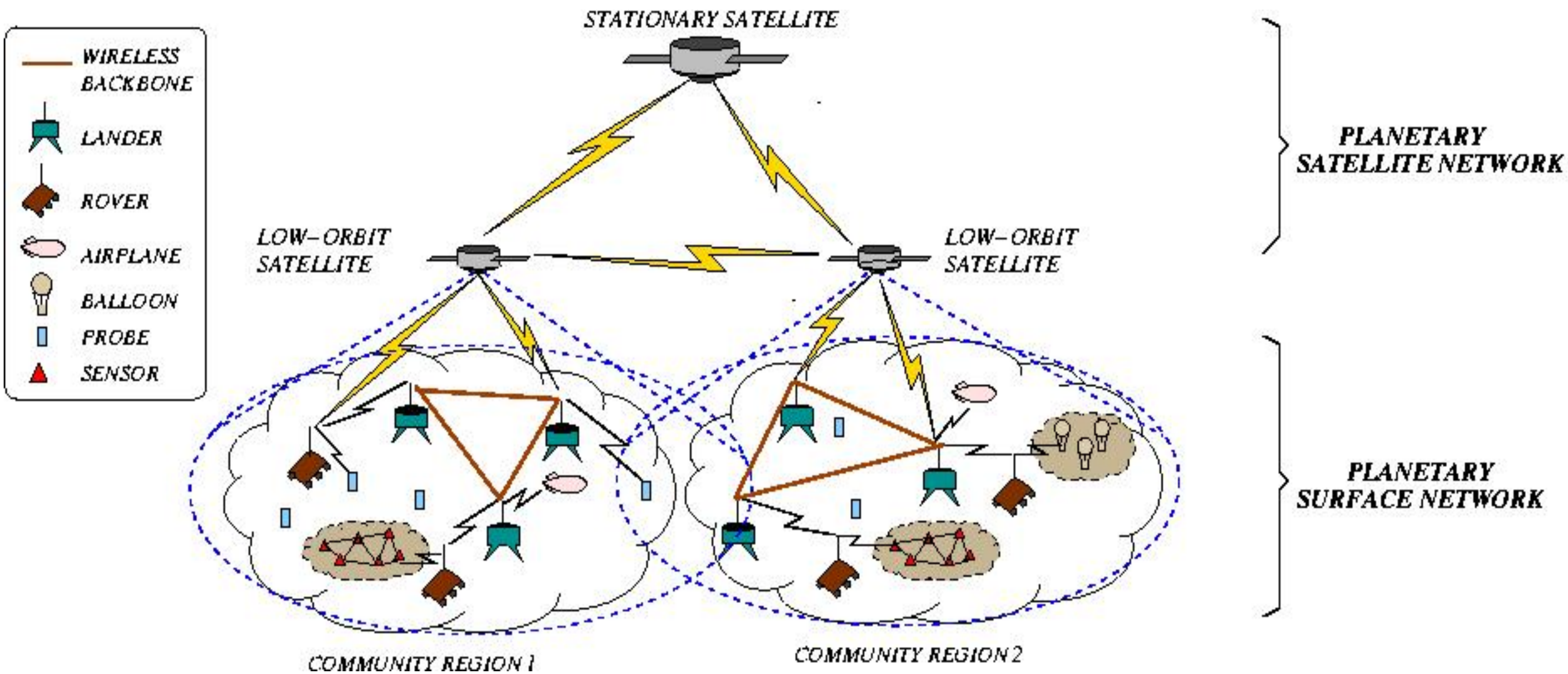


InterPlaNetary Internet Architecture



- InterPlaNetary Backbone Network
- InterPlaNetary External Network
- PlaNetary Network

PlaNetary Network Architecture

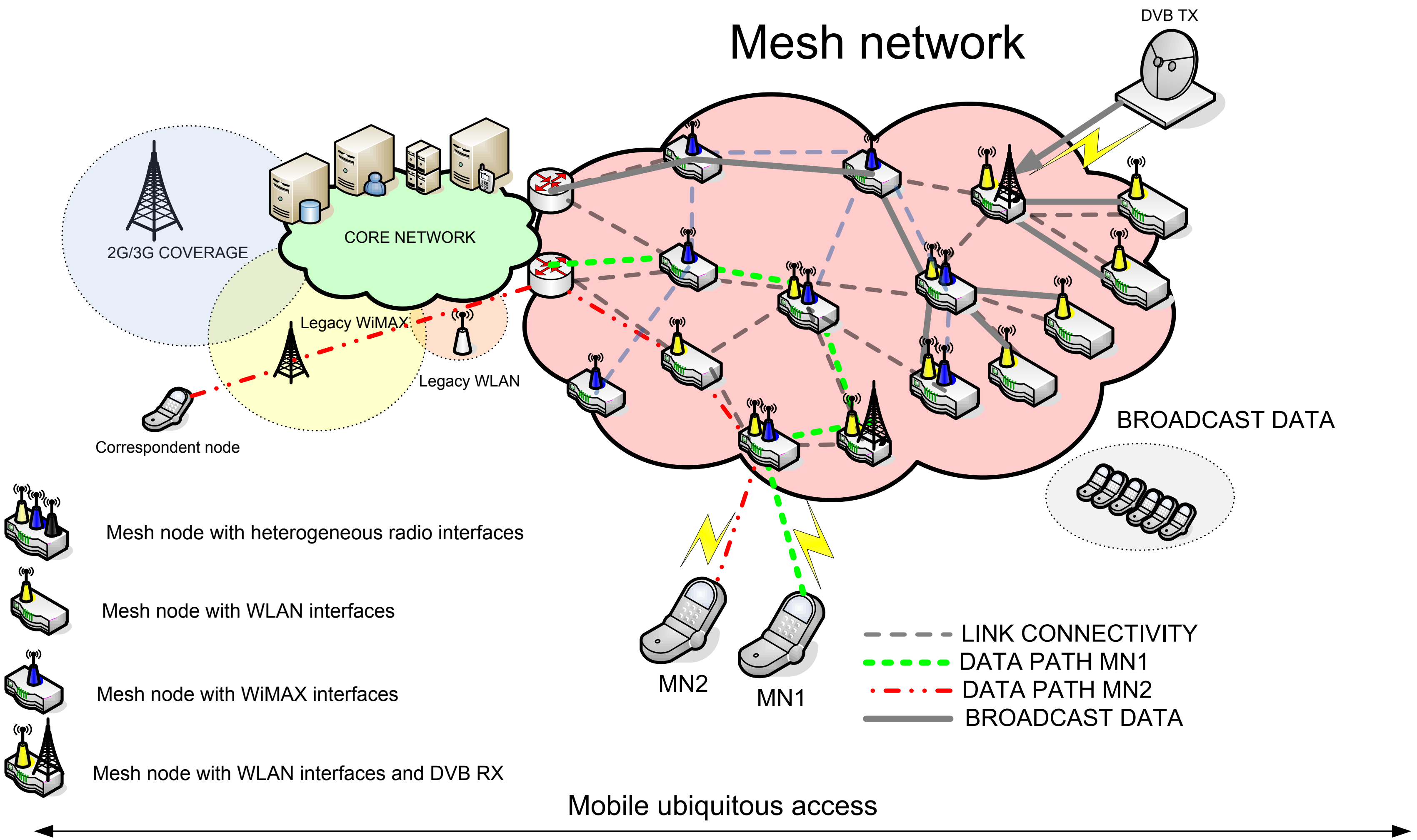


- PlaNetary Satellite Network
- PlaNetary Surface Network

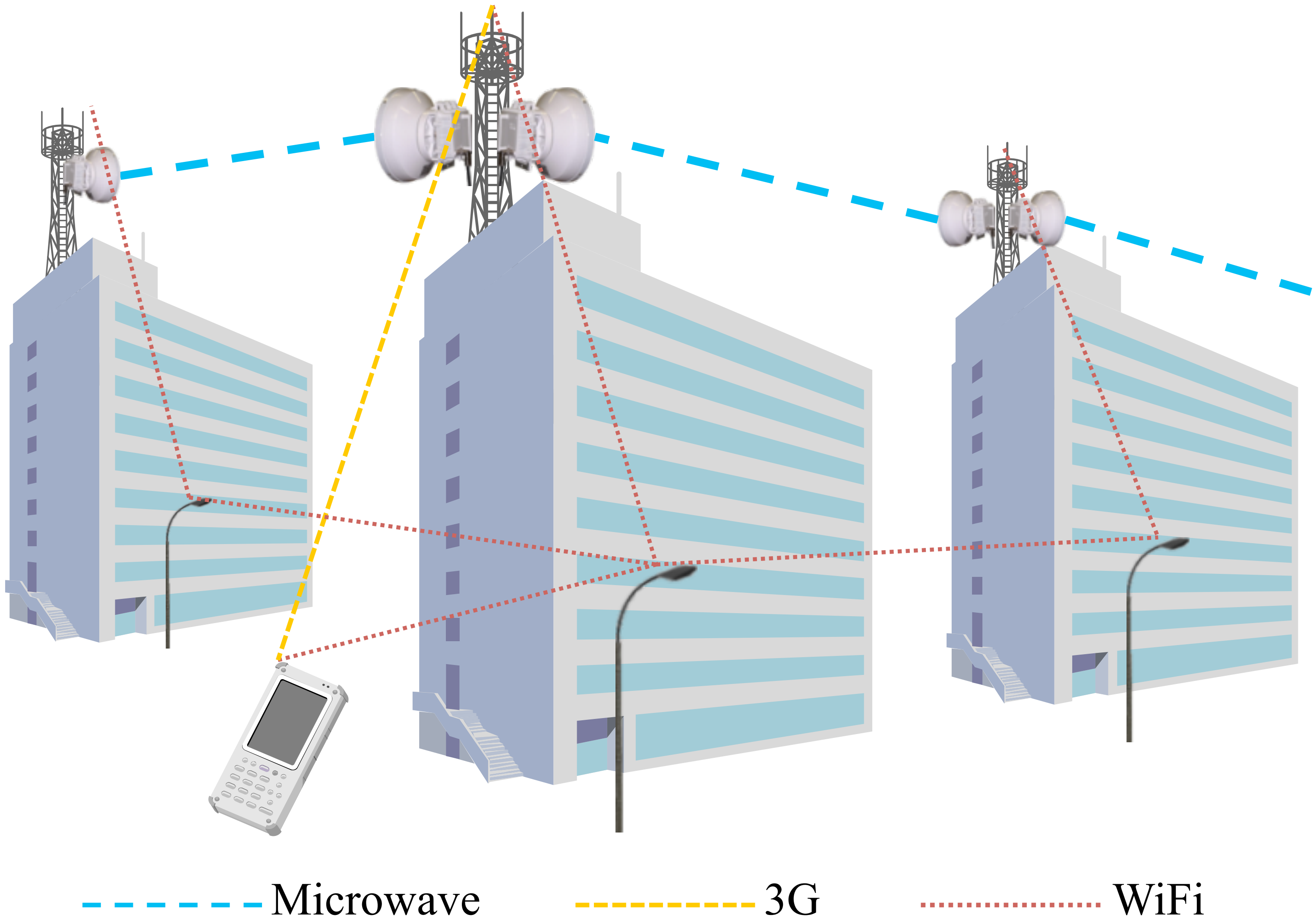
Challenges

- Extremely long and variable propagation delays
- Asymmetrical forward and reverse link capacities
- Extremely high link error rates
- Intermittent link connectivity, e.g., Blackouts
- Lack of fixed communication infrastructure
- Effects of planetary distances on the signal strength and the protocol design
- Power, mass, size, and cost constraints for communication hardware and protocol design
- Backward compatibility requirement due to high cost involved in deployment and launching processes

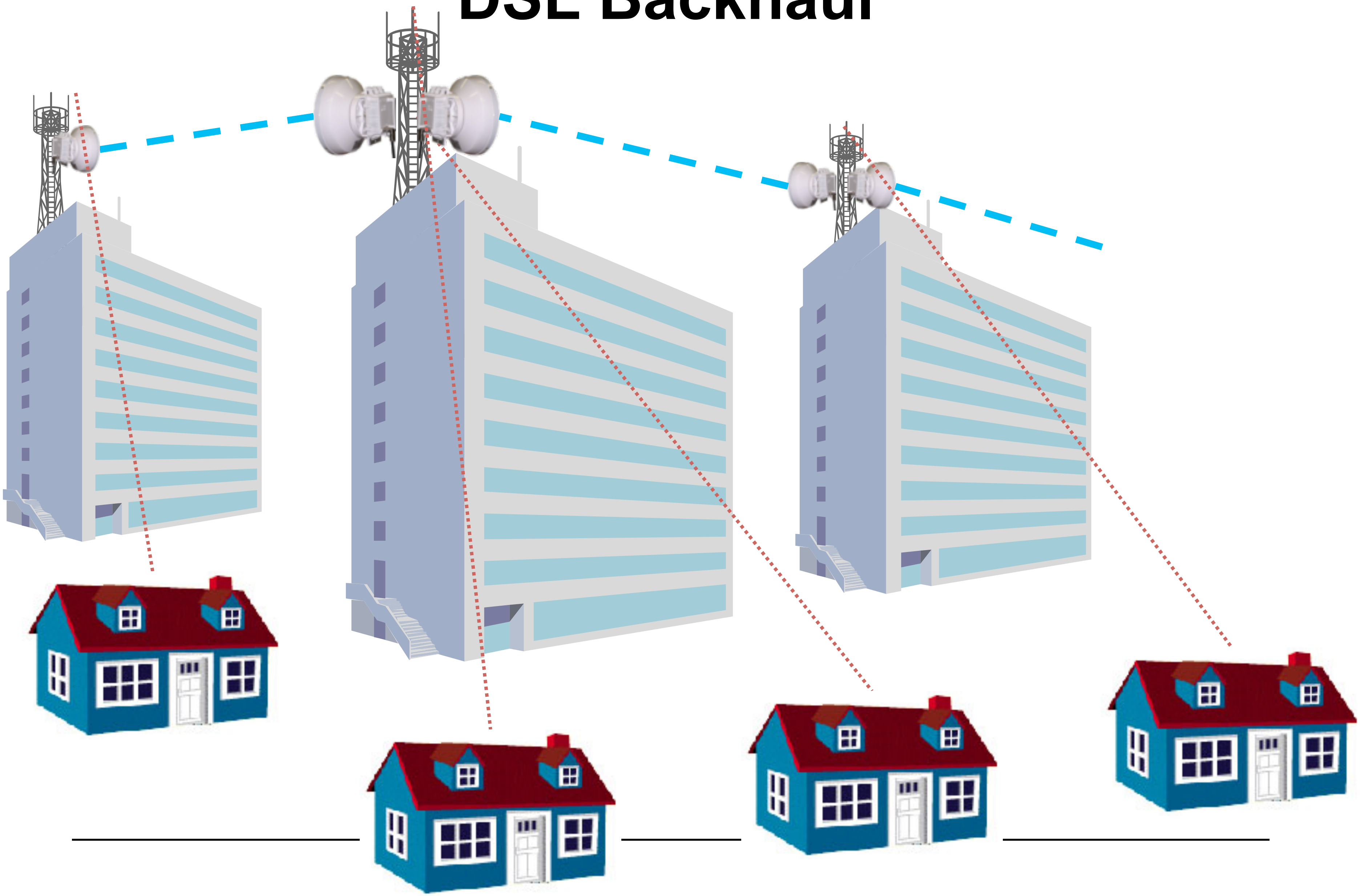
Heterogeneous Wireless Networks



WiFi Traffic Offload



DSL Backhaul



Additional Use Case Scenarios

"Stadium", proposed by BT

- low-cost, short-term provisioning of additional wireless access capacity
- triple-play QoS requirements

"Emergency Response Support", proposed by DT

- severe capacity constraints
- intermittent connectivity to core network
- sub-optimal node placement
- focus on group-communication