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# Extended Future Internet: an IP Pervasive Network Including Interplanetary Communication


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# Outline of the Presentation

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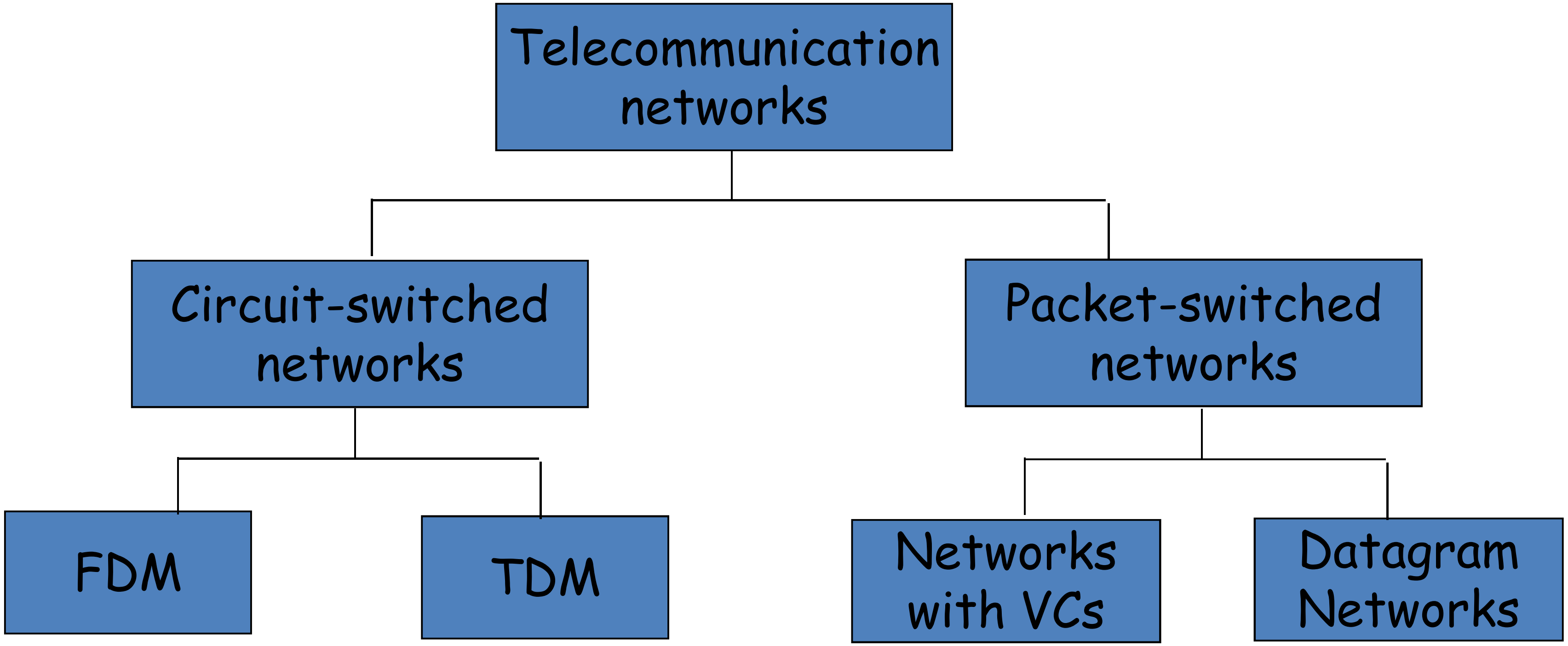
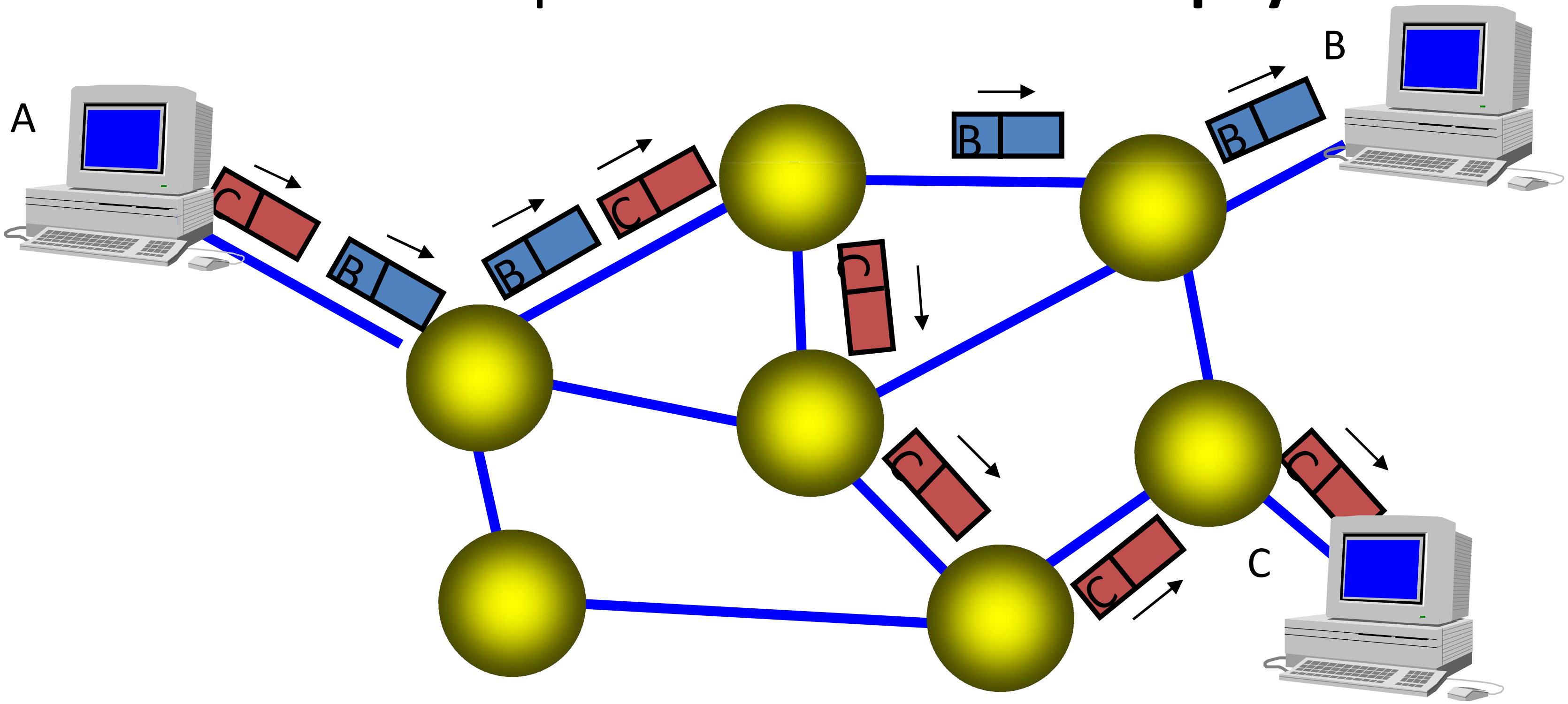
- What is the Internet
- Evolution of Internet
- Pervasive Computing
- Extended Future Internet
- Space Communications and Challenging Links
- DTN
- Future Challenges

# Network Taxonomy



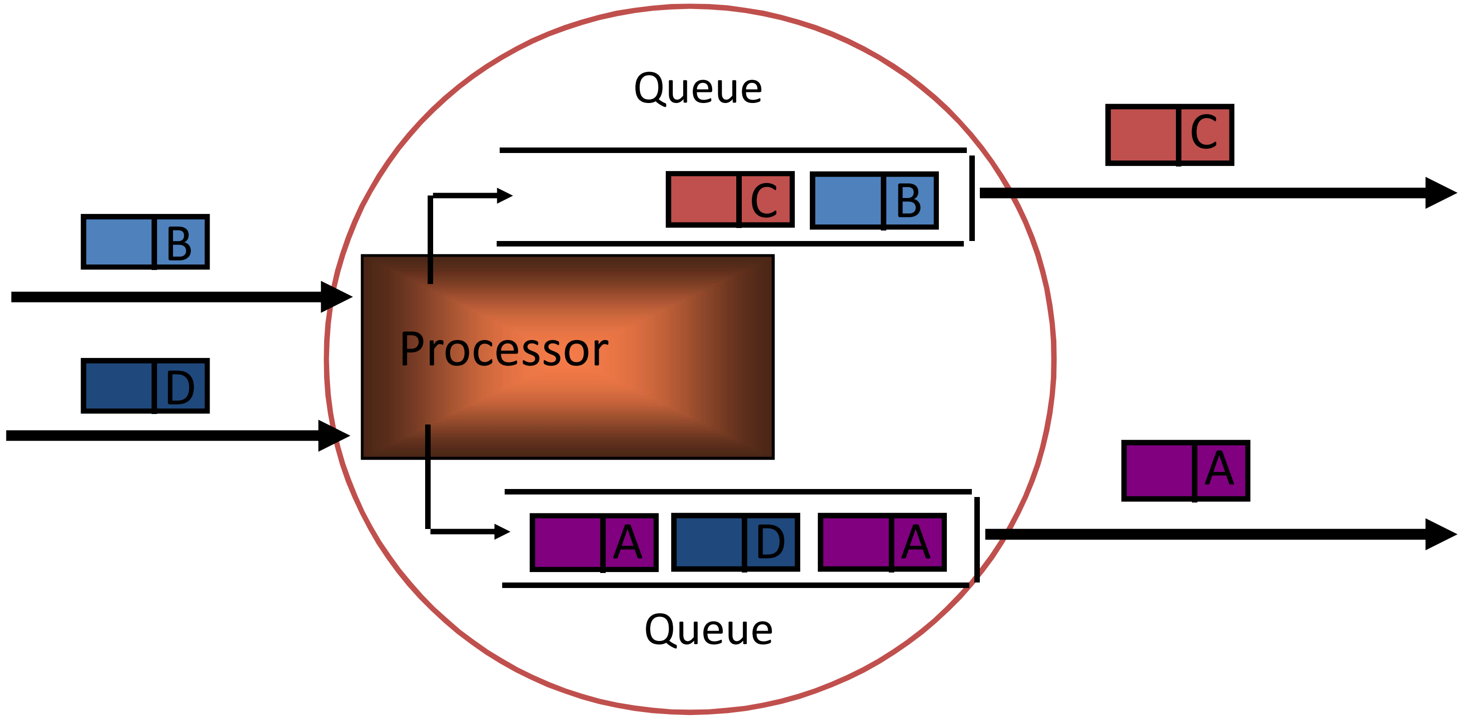
# Packet switching

- Information is structured into blocks ("chunks") of data called "packets"
- Packets are composed of a **header** and **payload**



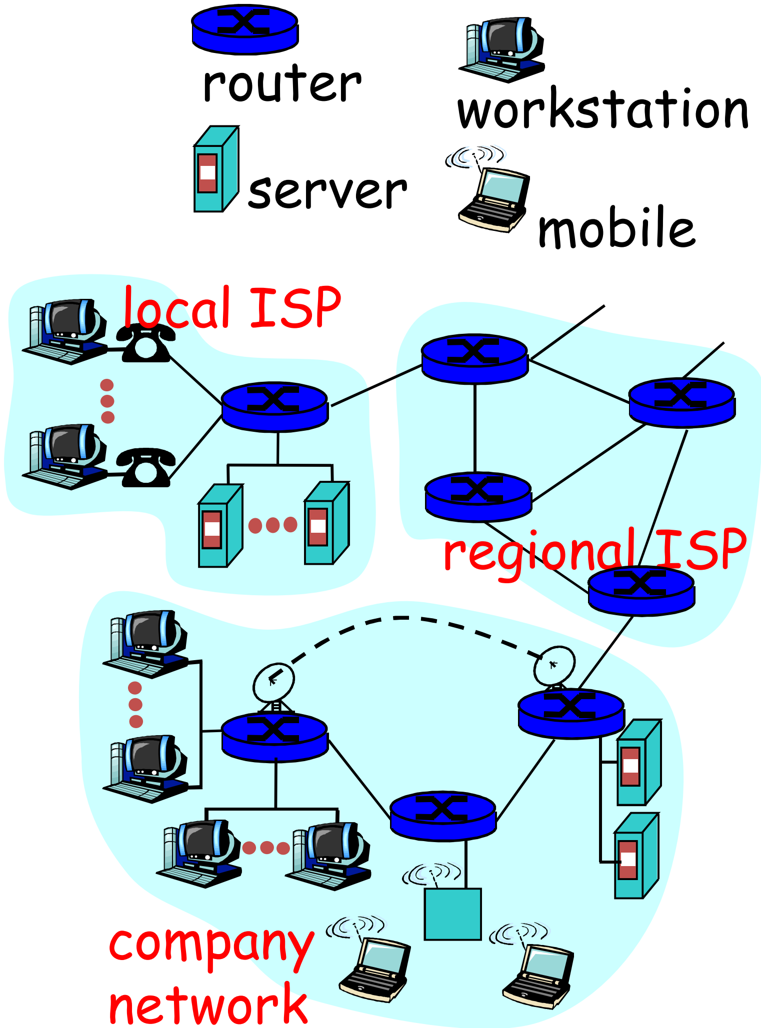
# Packet switching: network node structure

- **Store and forward**



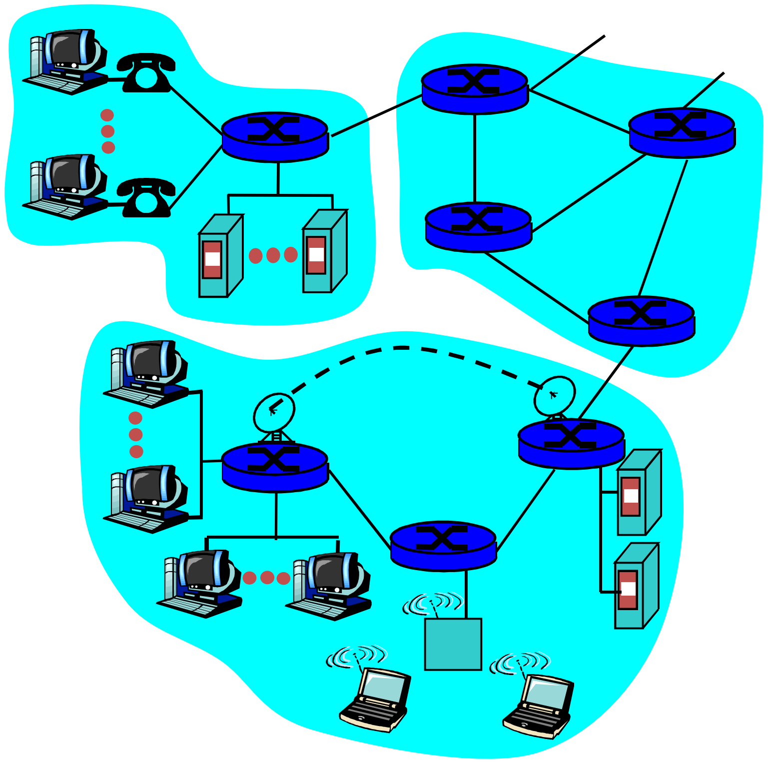
# Internet

- *protocols* control sending, receiving of msgs
- *Internet: "network of networks"*
- Internet standards



# Internet

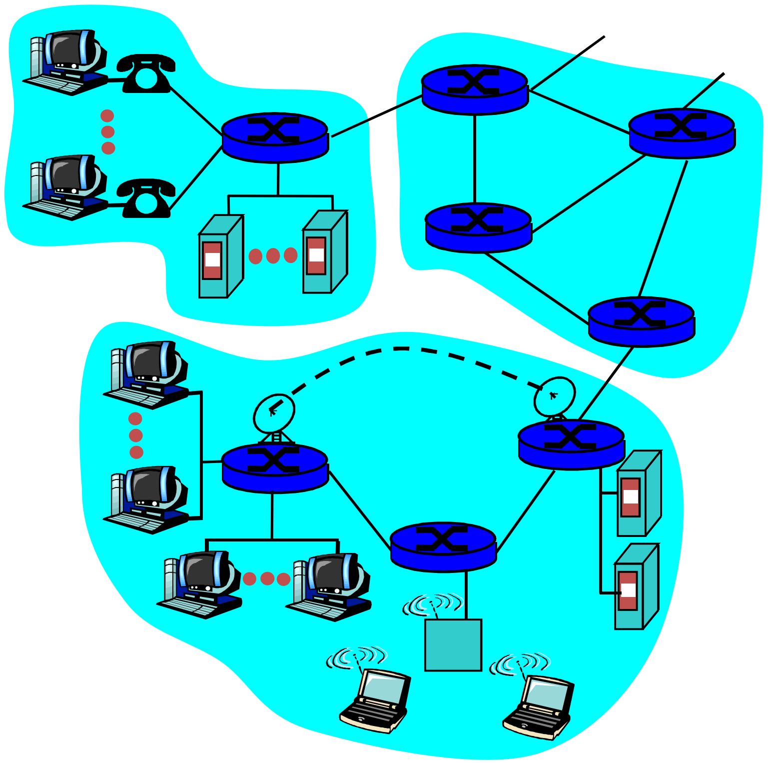
- communication *infrastructure* enables distributed applications:
- communication services provided to apps:



# Internet



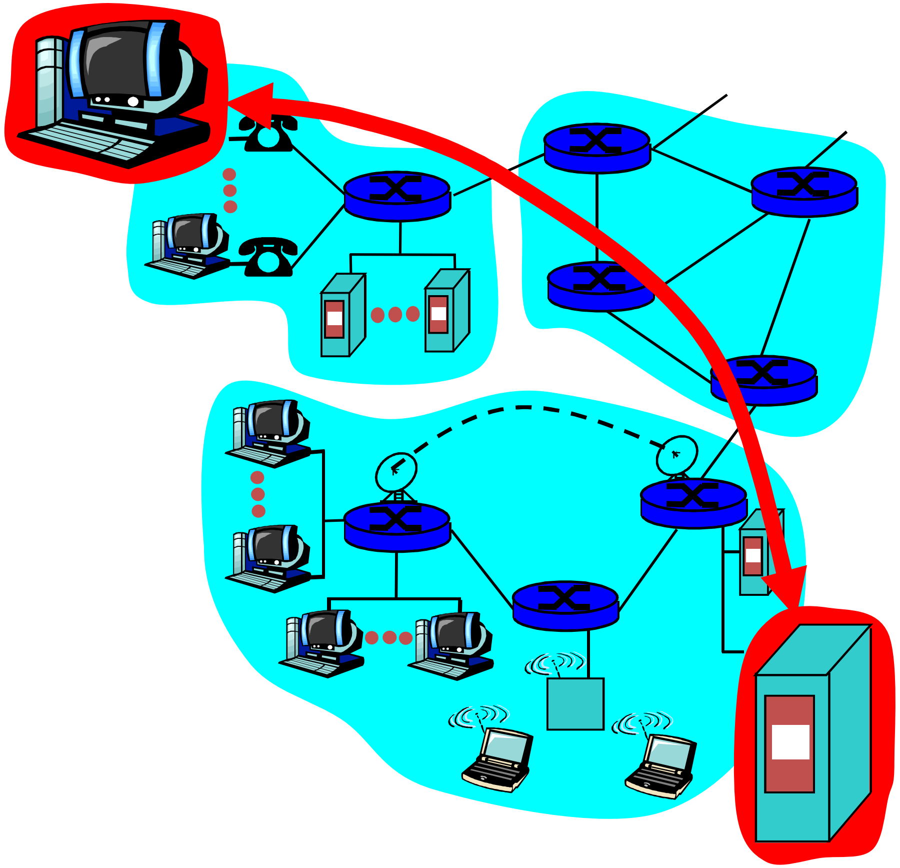
- network edge:
- network core:
- access networks, physical media



# Internet

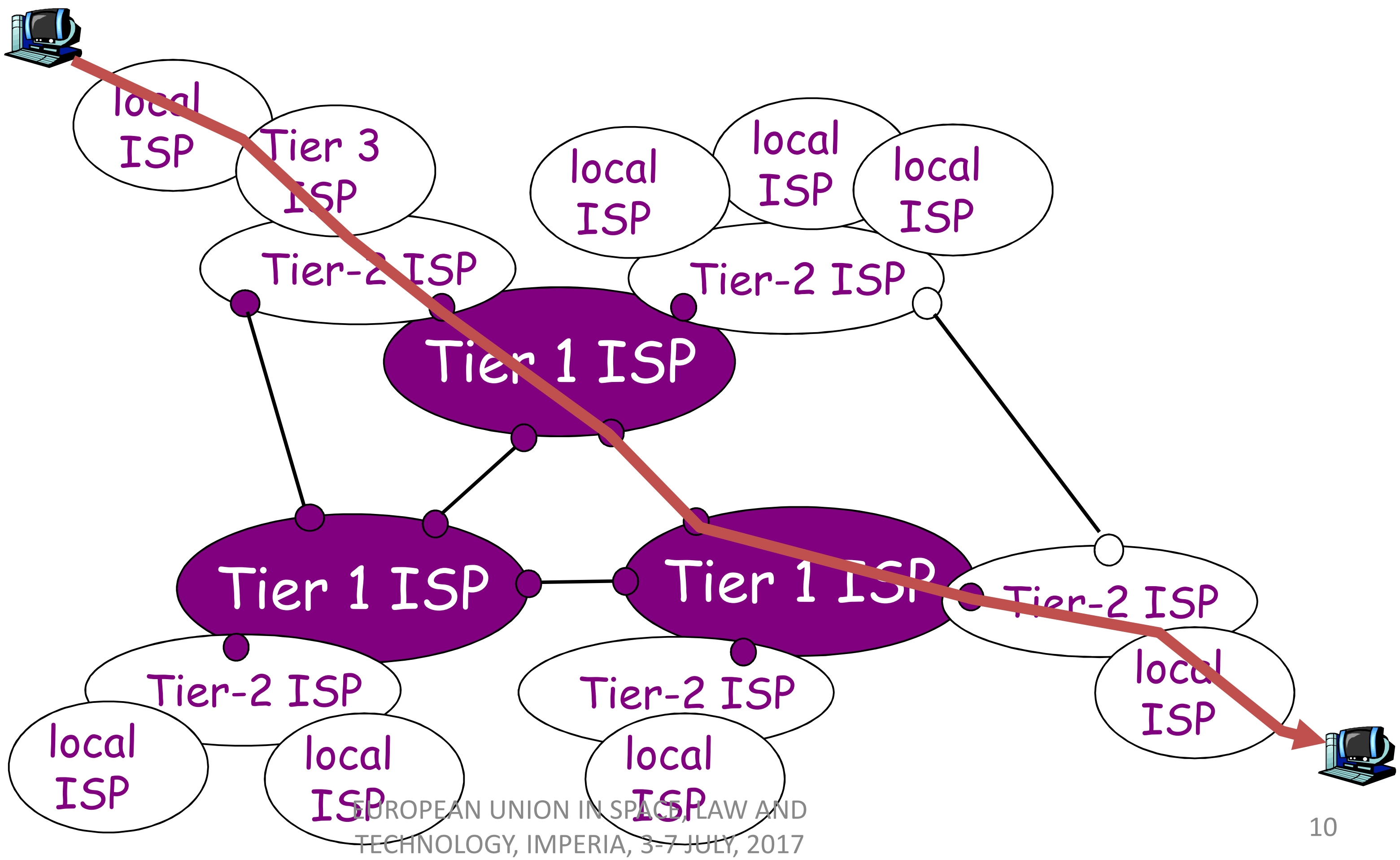


- end systems (hosts)
- client/server model
- peer-peer model

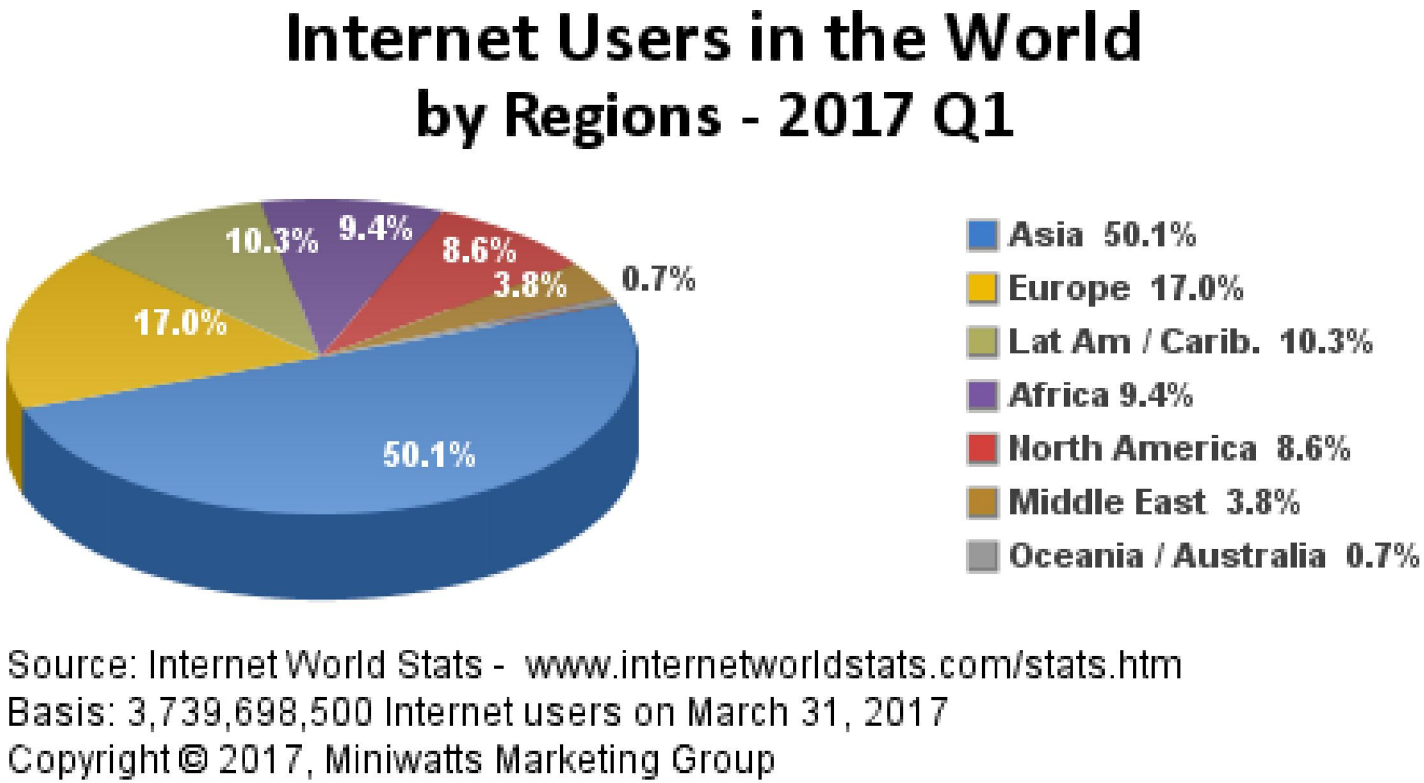


# Internet structure

- A packet passes through many networks



# Internet users (statistics)



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# Evolution of Internet (statistics)

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| WORLD INTERNET USAGE AND POPULATION STATISTICS MARCH 31, 2017 - Update | | | | | | |
|---|---|---|---|---|---|---|
| **World Regions** | **Population ( 2017 Est.)** | Population % of World | Internet Users 31 Mar 2017 | Penetration Rate (% Pop.) | Growth 2000-2017 | Internet Users % |
| Africa | 1,246,504,865 | 16.6 % | **353,121,578** | 28.3 % | 7,722.1% | 9.4 % |
| Asia | 4,148,177,672 | 55.2 % | **1,874,136,654** | 45.2 % | 1,539.6% | 50.1 % |
| Europe | 822,710,362 | 10.9 % | **636,971,824** | 77.4 % | 506.1% | 17.0 % |
| Latin America / Caribbean | 647,604,645 | 8.6 % | **385,919,382** | 59.6 % | 2,035.8% | 10.3 % |
| Middle East | 250,327,574 | 3.3 % | **141,931,765** | 56.7 % | 4,220.9% | 3.8 % |
| North America | 363,224,006 | 4.8 % | **320,068,243** | 88.1 % | 196.1% | 8.6 % |
| Oceania / Australia | 40,479,846 | 0.5 % | **27,549,054** | 68.1 % | 261.5% | 0.7 % |
| WORLD TOTAL | **7,519,028,970** | **100.0 %** | **3,739,698,500** | **49.7 %** | **936.0%** | **100.0 %** |

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# Evolution of Internet (statistics) Penetration Rates -2008

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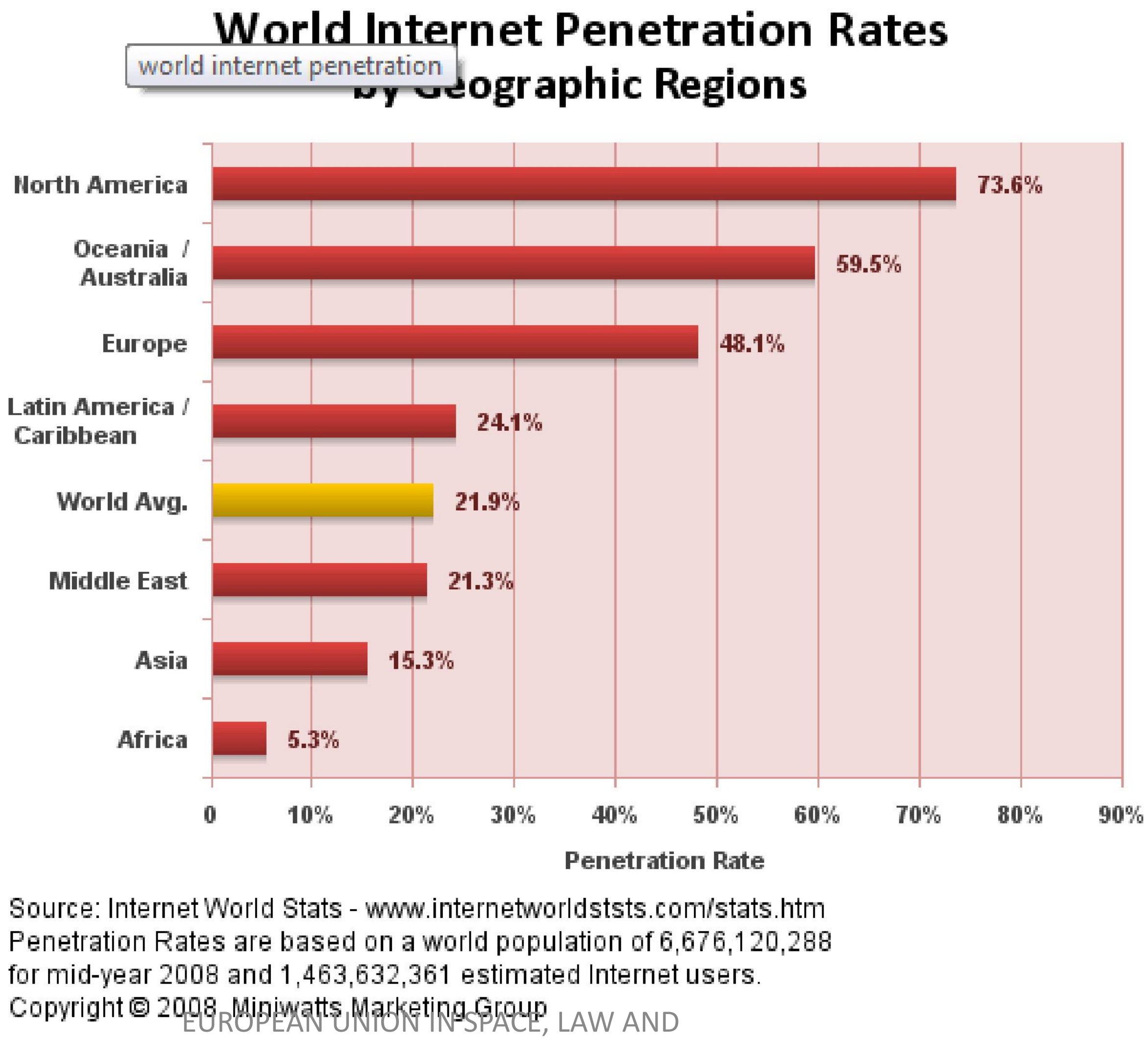
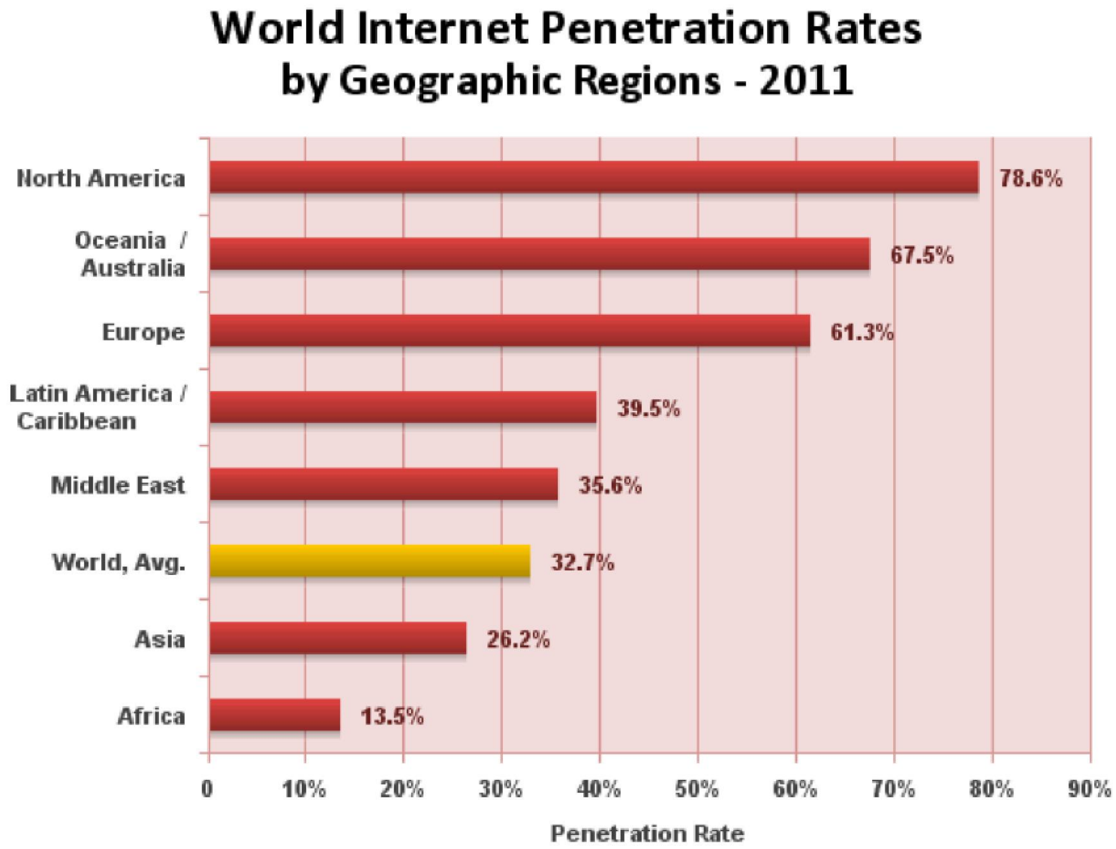
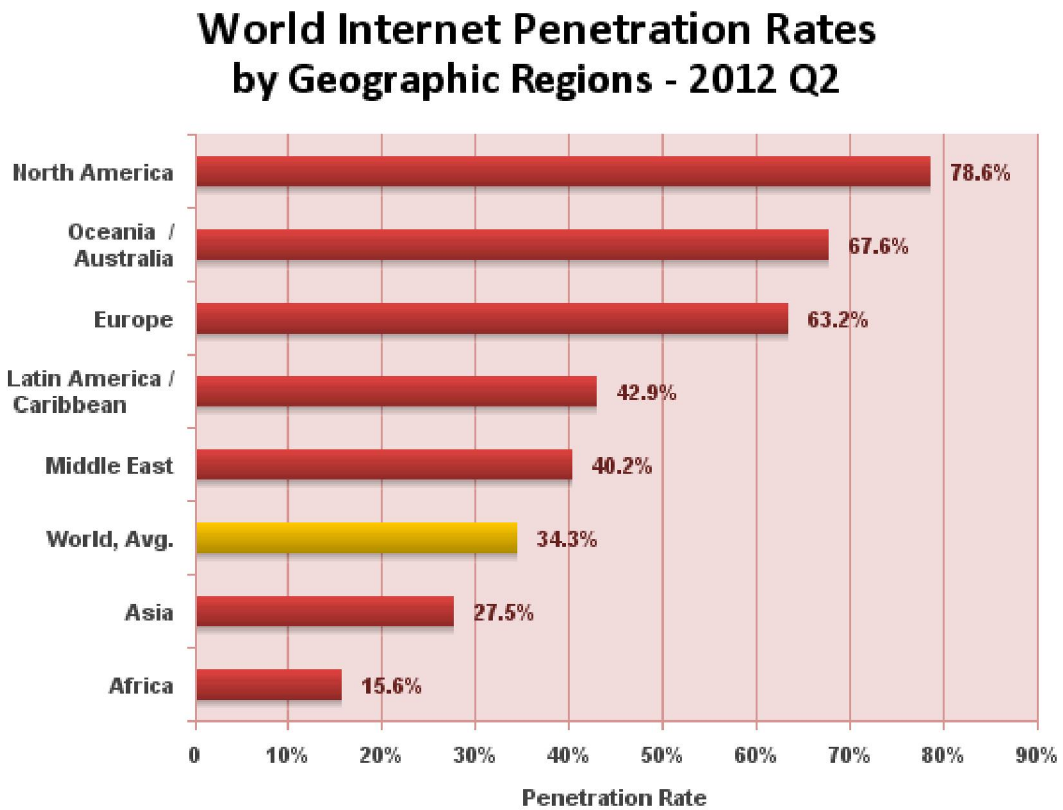


# Evolution of Internet (statistics) Penetration Rates-2011




Source: Internet World Stats - www.internetworldststs.com/stats.htm
Penetration Rates are based on a world population of 6,930,055,154
and 2,267,233,742 estimated Internet users on December 31, 2011.
Copyright © 2012, Miniwatts Marketing Group

# Evolution of Internet (statistics) Penetration Rates-2012




Source: Internet World Stats - www.internetworldststs.com/stats.htm
Penetration Rates are based on a world population of 7,017,846,922
and 2,405,518,376 estimated Internet users on June 30, 2012.
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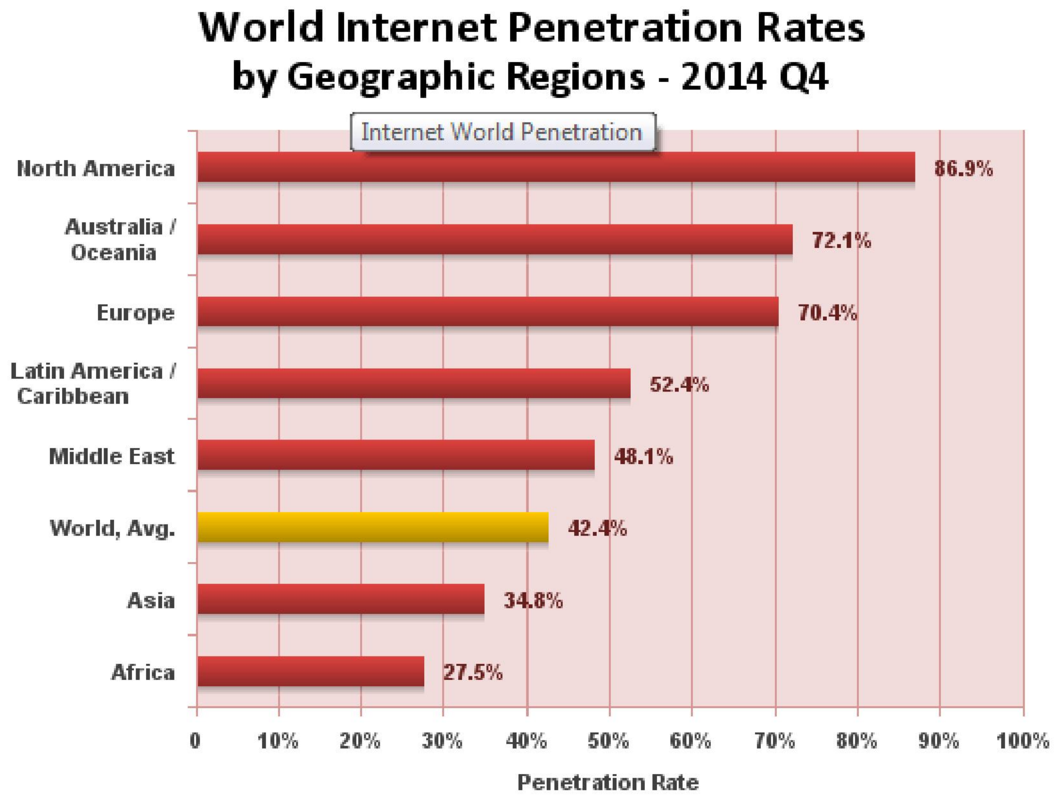
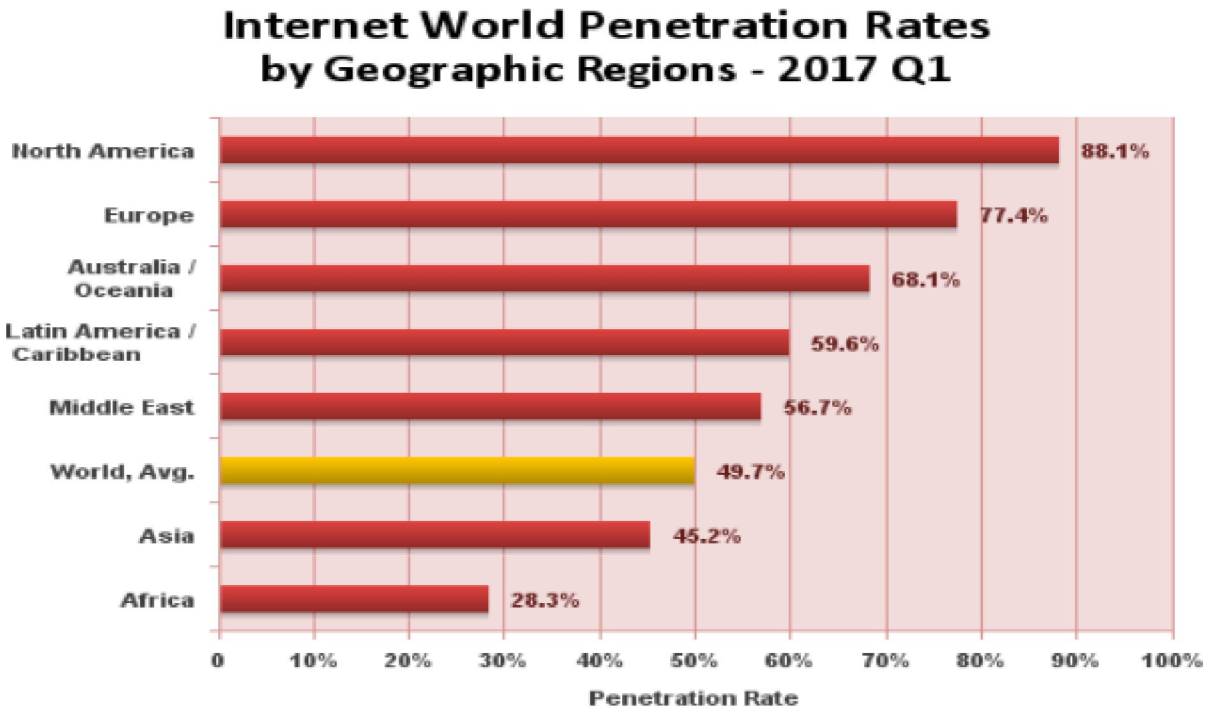
# Evolution of Internet (statistics) Penetration Rates-2014

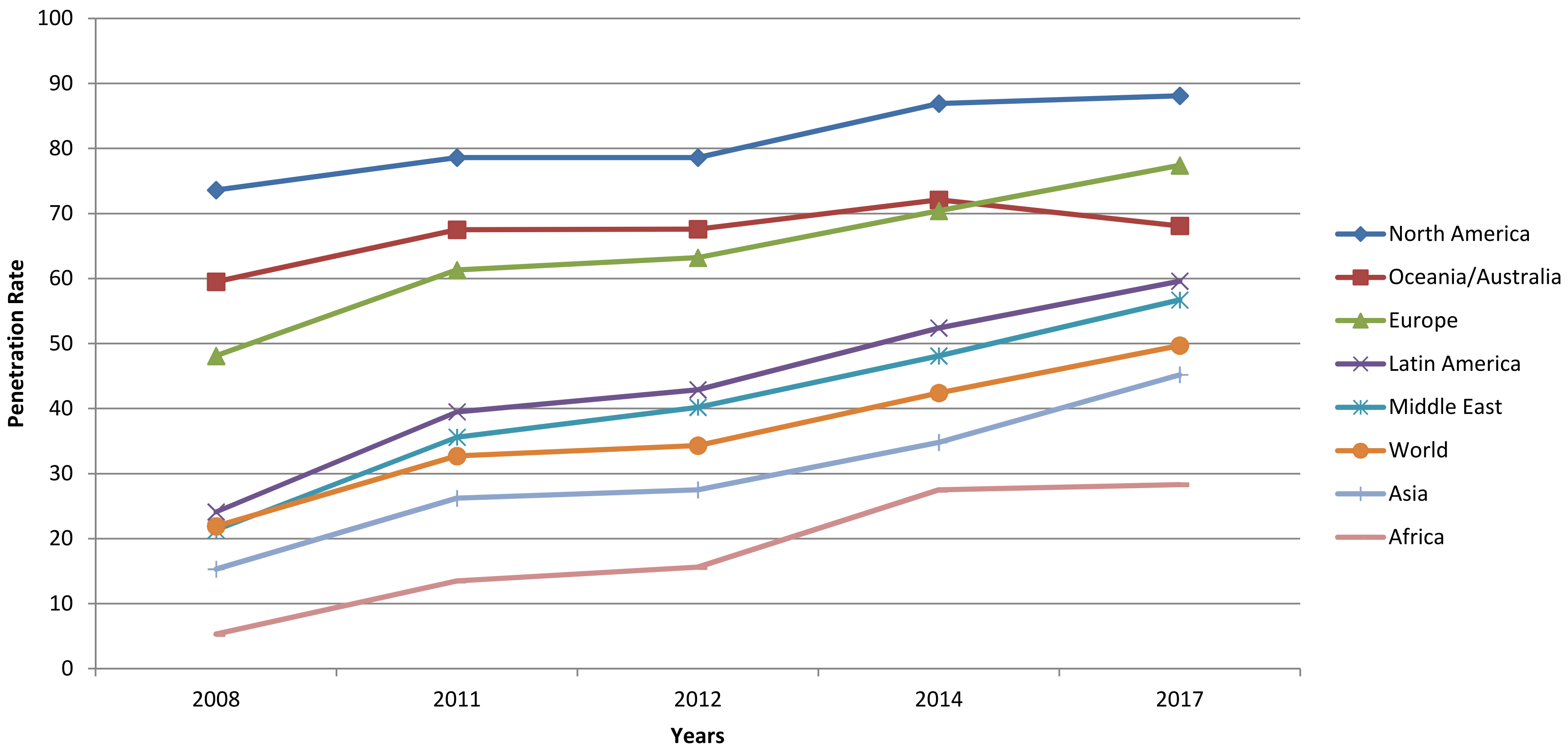



Source: Internet World Stats - www.internetworldststs.com/stats.htm
Penetration Rates are based on a world population of 7,264,623,793
and 3,079,339,857 estimated Internet users on Dec 31, 2014.

# Evolution of Internet (statistics) Penetration Rates-2017



# Evolution of Internet (statistics) Penetration Rate variation years



# Evolution of Internet

- Internet is widespread throughout the world

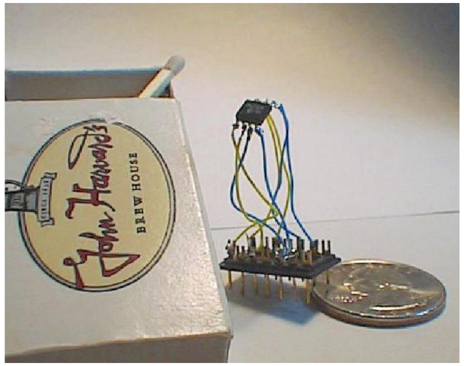
- Is Pervasive Computing real?

# Pervasive Computing
# General Concepts

- The Computer for the 21° Century by Mark Weiser
- This article first appeared in Scientific American, Vol. 265, No. 3 (September 199l), pp. 94-104
- “In our experimental embodied virtuality, doors open only to the right badge wearer, rooms greet people by name, telephone calls can be automatically forwarded to wherever the recipient may be, receptionists actually know where people are, computer terminals retrieve the preferences of whoever is sitting at them, and appointment diaries write themselves. “

# Examples of Internet terminals (hosts)





# Pervasive Computing General Concepts

- The paradigm of pervasive computing envisages a world where a wide set of quantities (vibrations, heat, light, pressure, magnetic fields, ... ) are acquired through sensors and transmitted through suitable seamless communication networks for information, decision, and control aim.
- Applications extend to all environments where monitoring and connecting the physical world is important: **civil protection, transportation, military, underwater, space monitoring and communications**, **critical infrastructures**, among others.

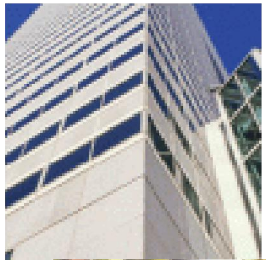
# What Is Critical Infrastructure



- The nation's critical infrastructure provides the essential services that underpin society and serve as the backbone of nation's economy, security, and health. We know it as the power we use in our homes, the water we drink, the transportation that moves us, the stores we shop in, and the communication systems we rely on to stay in touch with friends and family.
- There are 16 critical infrastructure sectors composing assets, systems, and networks, whether physical or virtual, so vital that their incapacitation or destruction would have a debilitating effect on security, national economic security, national public health or safety, or any combination thereof.

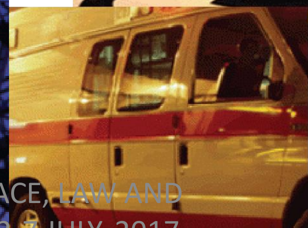
# Critical infrastructure sectors

- Chemical
- Commercial Facilities
- Communications
- Critical Manufacturing
- Dams
- Defense Industrial Base
- Emergency Services
- Energy



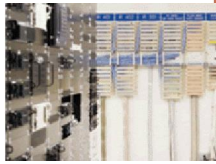
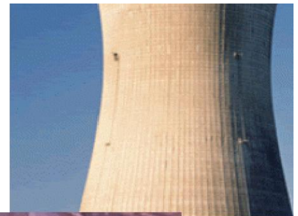
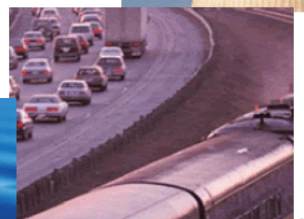
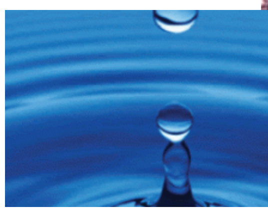




# Critical infrastructure sectors





- Financial Services
- Food and Agriculture
- Government Facilities
- Healthcare and Public Health
- Information Technology
- Nuclear Reactors, Materials, and Waste
- Transportation Systems
- Water and Wastewater Systems

# Pervasive Computing
# Interdisciplinary Research



- Interdisciplinary advances are required to innovate in the field of pervasive computing and networking:
  - new communication and networking solutions,
  - new and less complex operating systems,
  - miniaturized memorization capacity,
  - innovative decision algorithms,
  - efficient signal processing,
  - context-aware solutions.

# Pervasive Computing
# Internet of Things



- The aim is to create a pervasive network of heterogeneous devices which communicate data with each other and with other networking devices in a seamless way through heterogeneous network portions.
- In practice, the aim is connecting **anything, from anyplace, at anytime**.
- These are the three keywords of the Internet of Things paradigm, born independently of pervasive networking, but now strictly connected to it.

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# Pervasive Computing
# Future Internet

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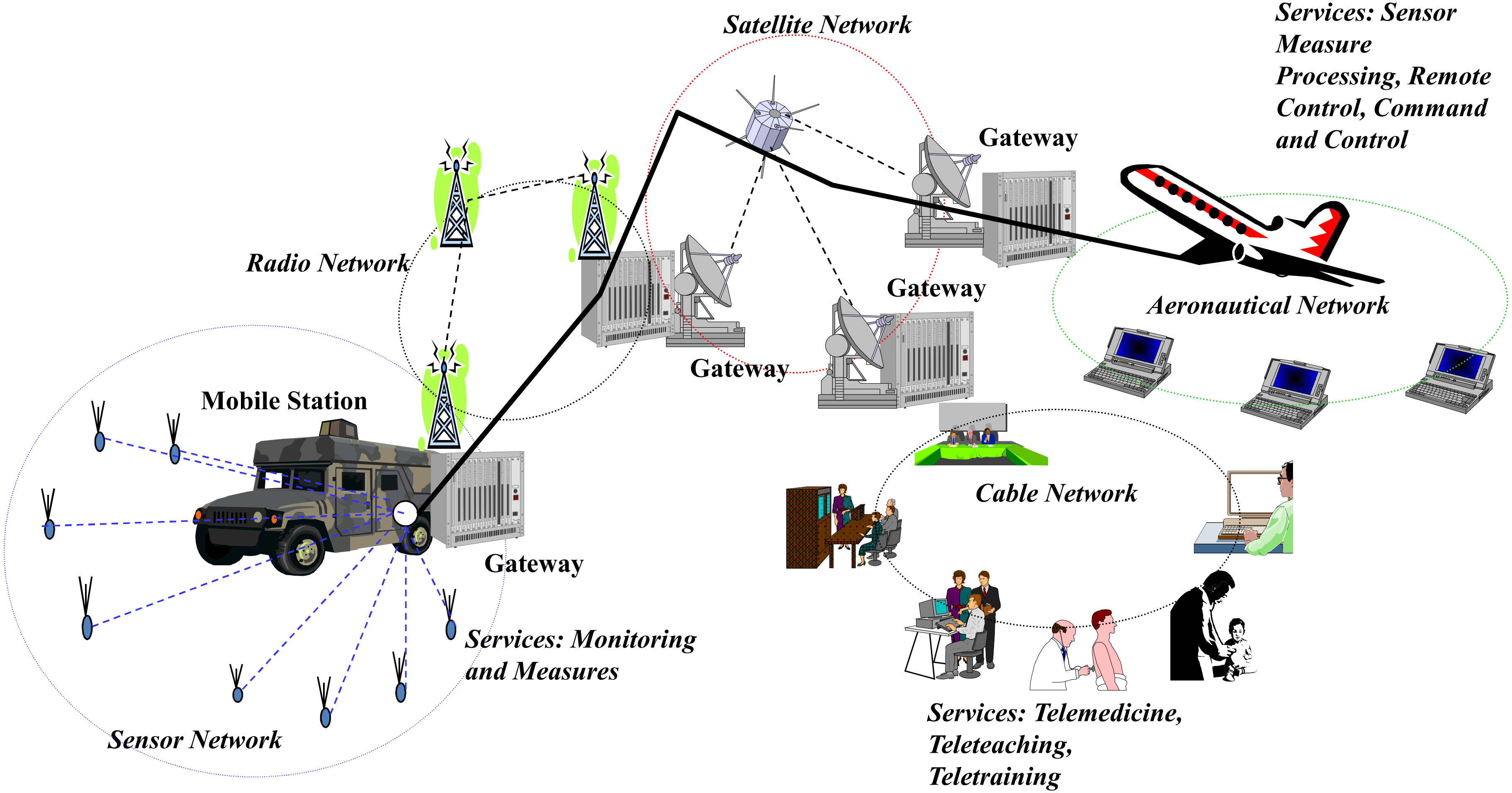
- In practice, a pervasive network is a telecommunication network composed of heterogeneous devices, differentiated for size, dynamics, and functions; and connected through heterogeneous communication solutions.
- This operative framework is also called Future Internet, an IP (Internet Protocol) pervasive network of networks, where end systems include non-IP-based devices, like sensors.
- The concept of Future Internet has no explicit limits. It may include interplanetary communication, environment that needs dedicated technologies and protocols and, up to now, has used particular and isolated communication networks.

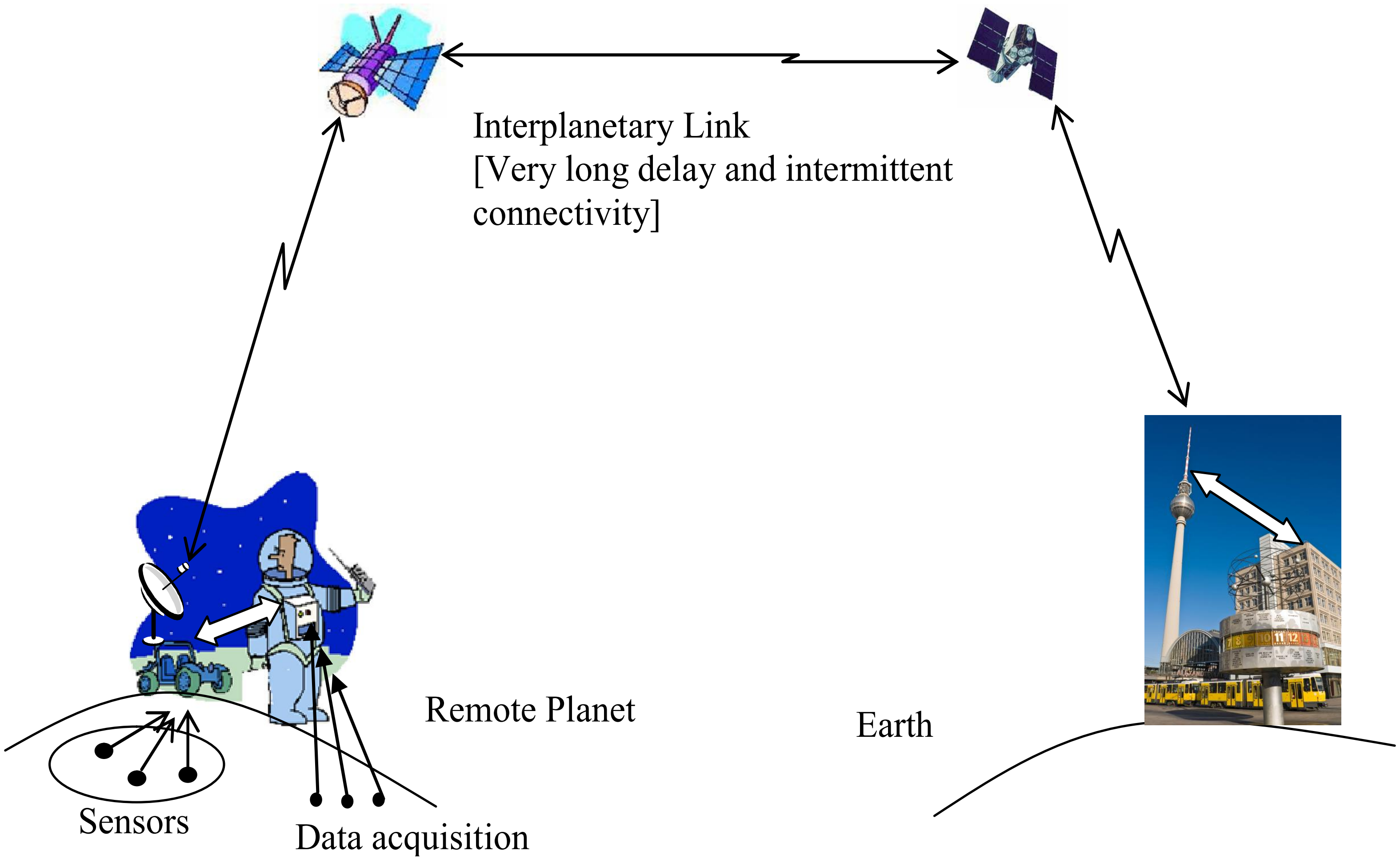
# Pervasive Computing
# Future Internet Extension

- To extend the idea of pervasive communications including interplanetary and other challenging links.

# Pervasive Computing Example Network



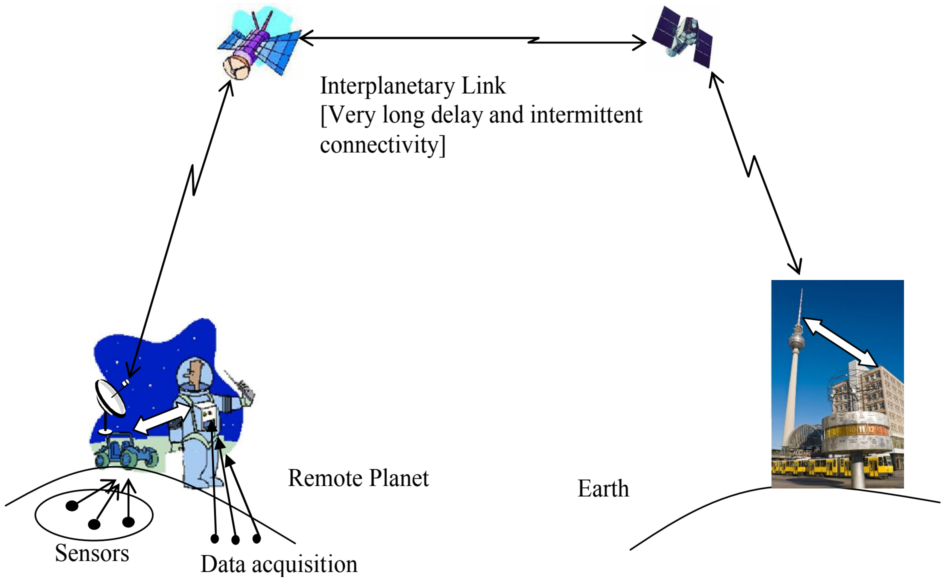
# Pervasive Computing
# Other Possible Example Networks

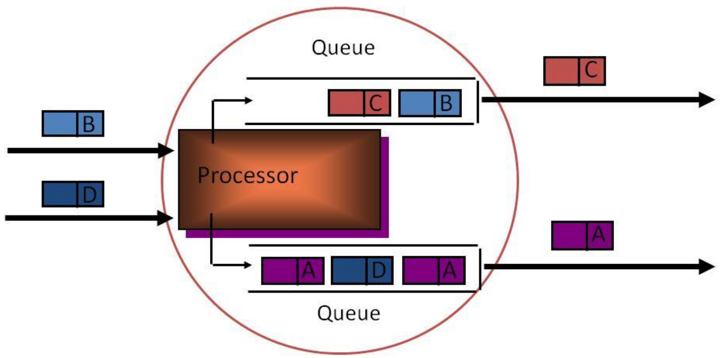


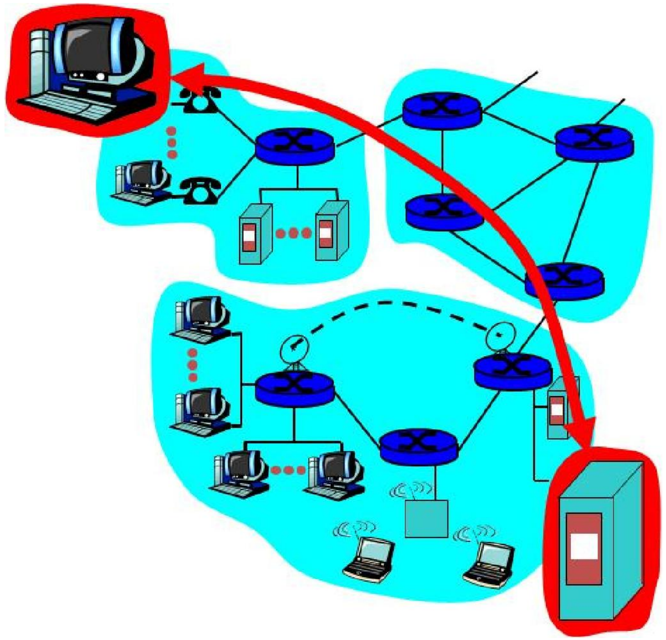
# Pervasive Computing
# Other Possible Example Network

Remote Area

# Future Interplanetary Interne



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# Space Communications and Challenging Links

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- Extending the idea of pervasive communications including interplanetary and other challenging links implies adding to the classical problems of pervasive communications such as **quality of service, mobility and security**, the peculiarities of interplanetary links such as **intermittent connectivity, disruptive links, large and variable delays, and high bit error rates** which are currently tackled through the paradigm of Delay Tolerant Networks (DTNs).

# Space Communications and Challenging Links

- Satellite systems used to connect isolated and rural areas have to cope with a series of challenges
  - long round trip times (RTTs);
  - likelihood of data loss due to errors on the communication link;
  - possible channel disruptions;
  - coverage issues at high latitudes and in challenging terrain.

# Space Communications and Challenging Links

- These problems are magnified in space communications characterized by
  - huge distances among network nodes,
  - extremely long delays,
  - intermittent connectivity.
- At the same time, a space communications system must be reliable over time, for example, due to the long duration of space missions. Moreover the importance of enabling Internet-like communications with space vehicles (as well as with rural areas) is increasing, making real the concept of extended Future Internet.

# DTN solution

- The Delay- and Disruption Tolerant Network (DTN) architecture introduces an overlay protocol that interfaces with either the transport layer or lower layers. **Each node of the DTN architecture can store information for a long time before forwarding it**.

# DTN solution



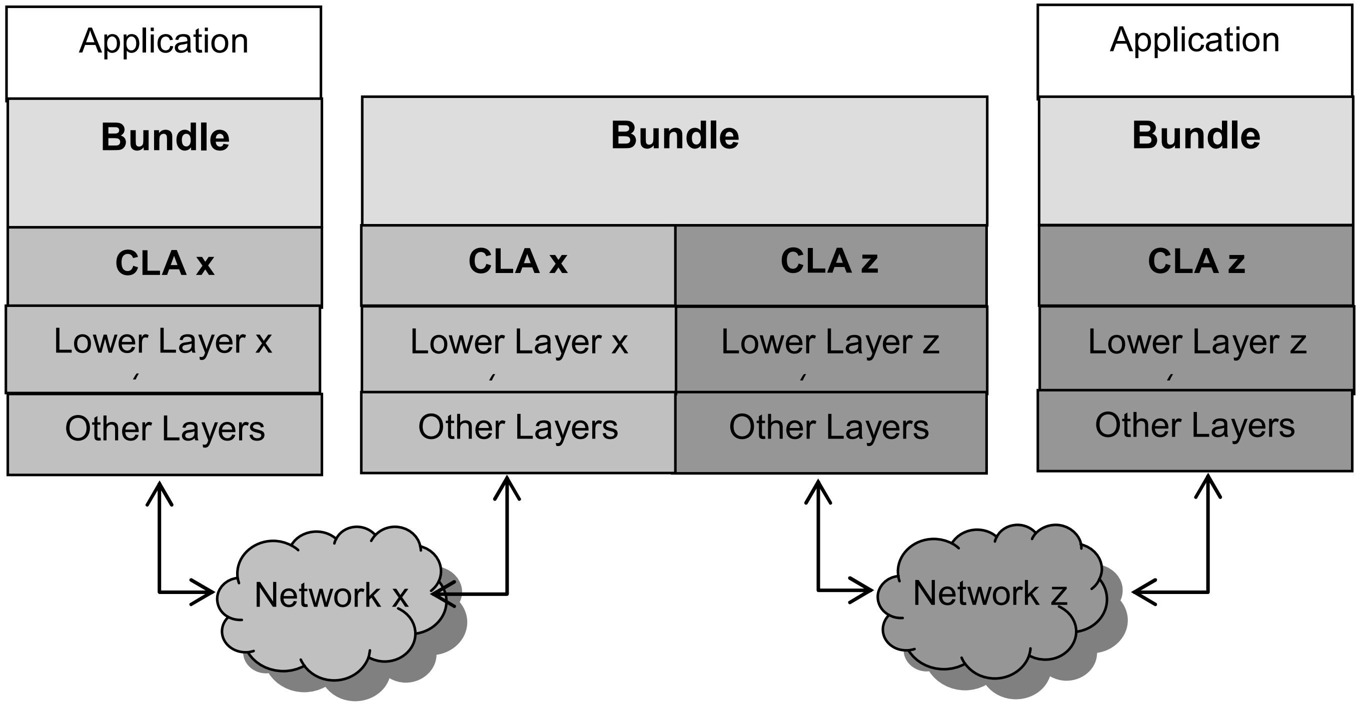
- The origin of the DTN concept lies in a generalization of requirements identified for **InterPlanetary Networking (IPN)**, where enormous latencies measured in tens of minutes, as well as limited and highly asymmetric bandwidth, must be faced.
- Nevertheless other scenarios, called “challenged networks”, such as **military tactical networking, sparse sensor networks**, and networking in developing or otherwise communications-challenged regions can benefit from the DTN solution.

# DTN solution



- Nodes on the path can provide the storage necessary for data in transit before forwarding it to the next node on the path.
- The contemporaneous end-to-end connectivity that Transmission Control Protocol (TCP) and other standard Internet transport protocols require in order to reliably transfer application data is not required. **In practice, in standard TCP/IP networks, which assume continuous connectivity and short delays, routers perform non-persistent (short-term) storage and information is persistently stored only at end nodes**.
- **In DTN networks information is persistently (long-term) stored at intermediate DTN nodes. This makes DTN much more robust against disruptions, disconnections, and node failures**.

# DTN Architecture

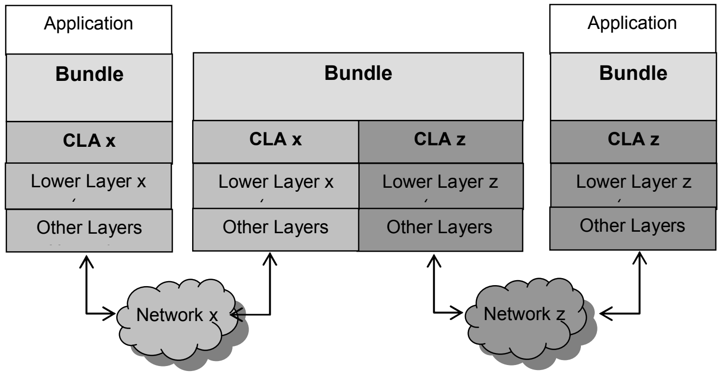


# Bundle Protocol



- The bundle protocol (BP) is an implementation of the DTN architecture where the basic unit to transfer data is a Bundle, a message which carries application layer protocol data units, sender and destination names, and any additional data required for end-to-end delivery.
- The BP can interface with different lower layer protocols through convergence layer adapters (CLAs). CLAs for TCP, UDP, Licklider Transmission Protocol (LTP), Bluetooth, and raw Ethernet have been defined. Each DTN node can use the best suited CLA for the forwarding operation.

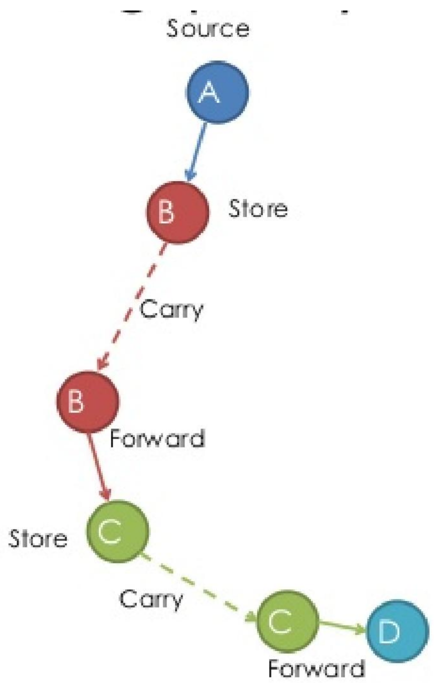
# Bundle Protocol

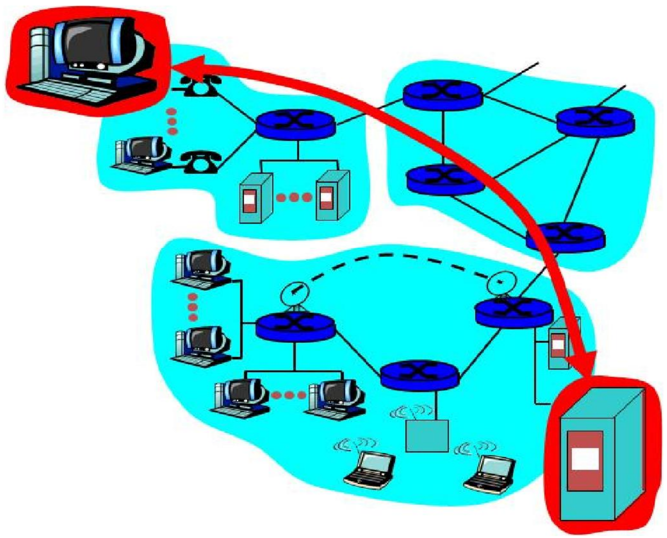



- DTN as an overlay
- Information storage at intermediate nodes

- **Custody Transfer**, where an intermediate node can take custody of a bundle, relieving the original sender of the bundle which might never have the opportunity to retransmit the application data due to physical or power reasons
- Proactive and Reactive Bundle Fragmentation, the former to tackle intermittent periodic connectivity when the amount of data that can be transferred is known *a priori*, the latter, which works *a posteriori*, when disruptions interrupt an ongoing bundle transfer;
- Late Binding, where, for example, when a bundle destination endpoint's identifier includes a Dynamic Name Server (DNS) name, only the CLA for the final DTN hop might have to resolve that DNS name to an IP address, while routing for earlier hops can be purely name based.

# DTN Node vs Router



The entire end-to-end path may be never available

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# Future Challenges

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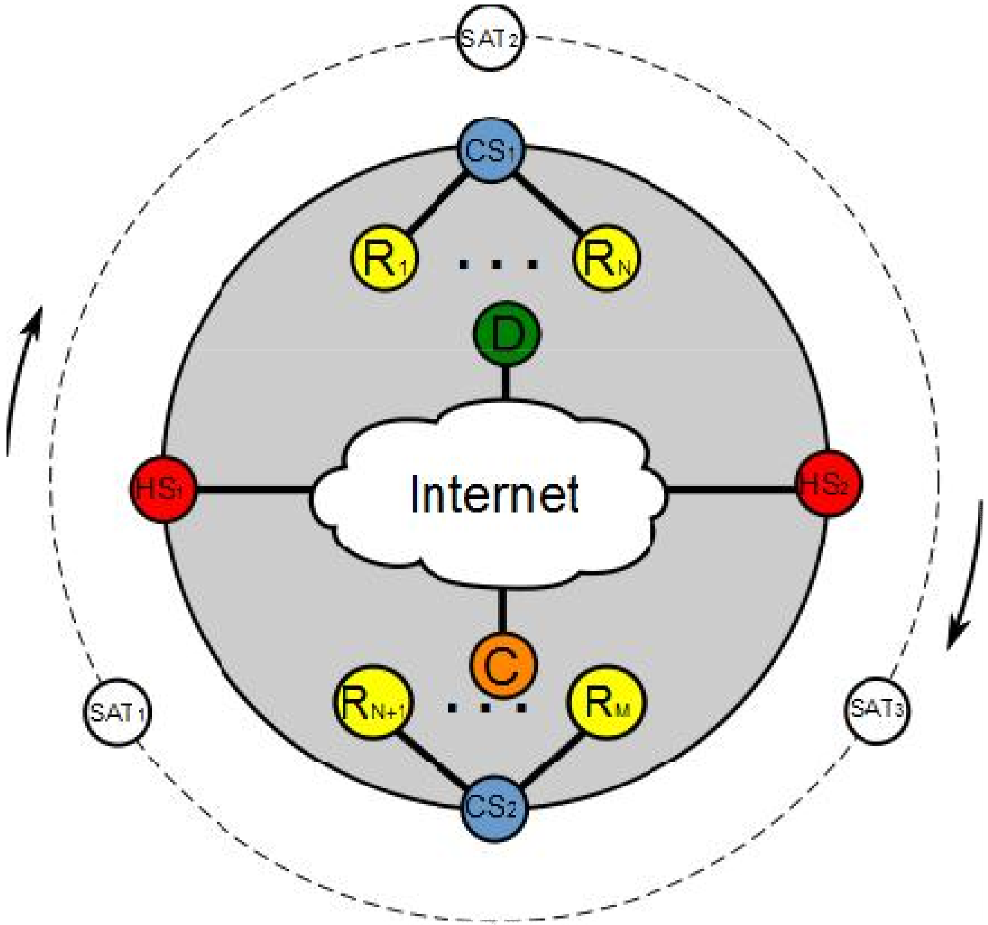
- Modelling
- Routing
- Congestion Control
- Legal Issues?

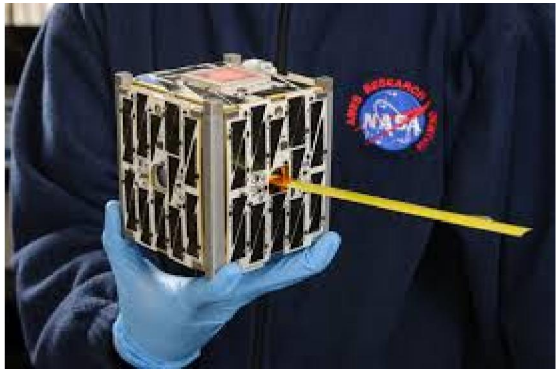
- Nanosatellites and DTN for rural communications

# Future Challenges



- Nanosatellites (research activity example)



# Small, micro and nanosatellites



- Small satellites, miniaturized satellites, or smallsats, are satellites of low mass and size, usually under 500 kg
- The term "microsatellite" or "microsat" is usually applied to the name of an artificial satellite with a mass between 10 and 100 kg. However, this is not an official convention and sometimes those terms can refer to satellites larger than that, or smaller than that (e.g., 1–50 kg)
- The term "nanosatellite" or "nanosat" is applied to an artificial satellite with a mass between 1 and 10 kg

| Group name | Mass (kg) |
|---|---|
| Large satellite | >1000 |
| Medium satellite | 500 to 1000 |
| Mini satellite | 100 to 500 |
| Micro satellite | 10 to 100 |
| Nano satellite | 1 to 10 |
| Pico satellite | 0.1 to 1 |
| Femto satellite | <0.1 |

# Nanosatellites

- The main reasons for the development and use of nanosatellites are, for now: enabling low data rate communications, gathering data from multiple points, and inspecting the activities of larger satellites.
- For example, CubeSat, a kind of nanosatellite that is launched into low-earth orbit and requires 0.1% of the cost of a classical LEO satellite, is aimed at enabling a constellation of nanosatellites for Earth imaging even if other applications are not excluded.
- Consequently, main reference applications are non-real time services. Low data rate real-time service (e.g. web browsing) might be provided at cost of a large number of nanosatellites in the constellation and of Earth stations.
- Otherwise, it is possible to refer to a sort of delay-tolerant web browsing where a larger delay than the one of regular web services may be tolerated

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# Contacts

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