Computer Networks Basic Protocols

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04/12/2018

Network Layer & Next Generation Wireless Networks

-Short Introduction-

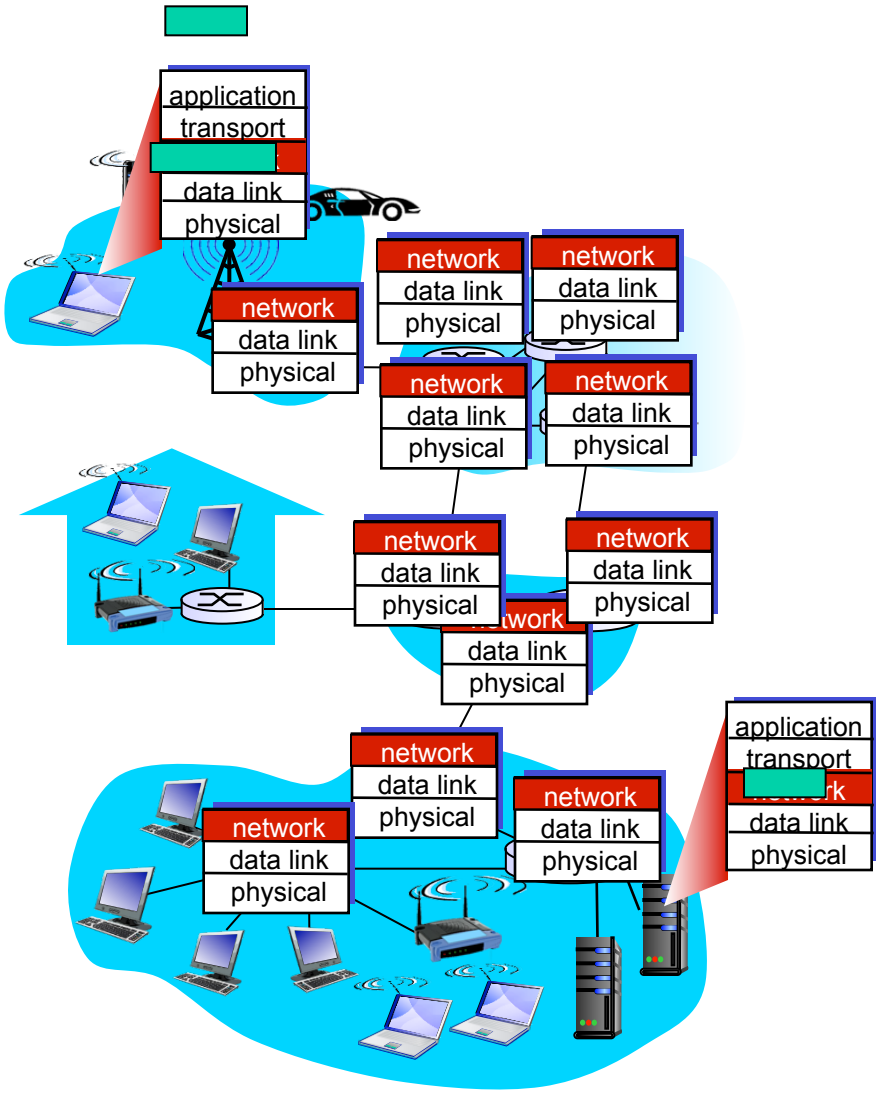
References:

-*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.

Network layer

- transport segment from sending to receiving host
- on sending side encapsulates segments into datagrams
- on receiving side, delivers segments to transport layer
- network layer protocols in *every* host, router
- router examines header fields in all IP datagrams passing through it



- Concerned with getting packets from source to destination
- Network layer must
  - know the subnet topology and
  - choose appropriate paths through it
- When source and destination are in different networks, network layer must handle
- Services provided to Transport Layer:
  - Should be independent of the subnet topology
  - Should be independent of the router
  - Transport Layer should be shielded from the number, type and topology of the subnets present
  - The network addresses available to the Transport Layer should use a uniform numbering plan

Network layer connection and connection-less service

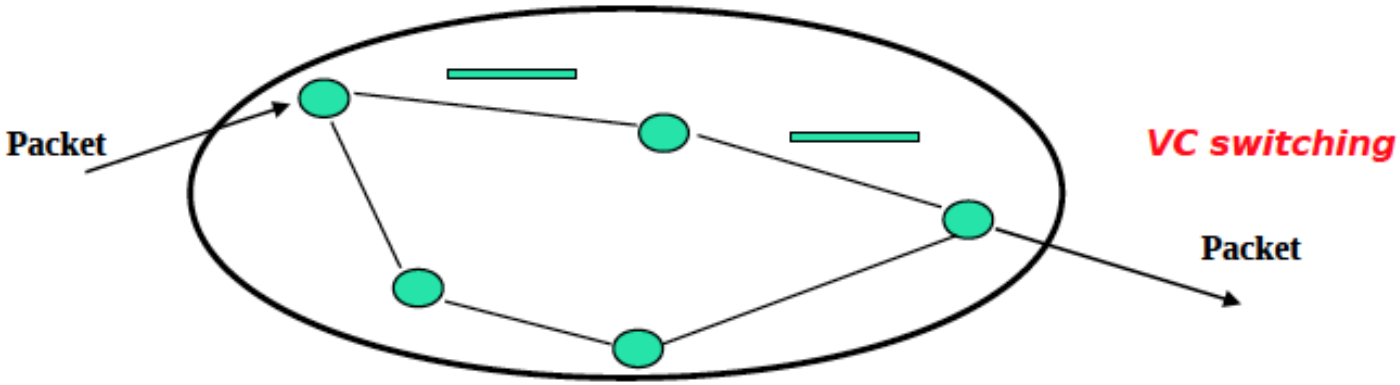
- **Datagram network** provides network-layer connectionless service

- **VC (virtual circuit) network** provides network-layer connection service

Connection Oriented (VC Networks)

"source-to-dest path behaves much like *telephone circuit*"

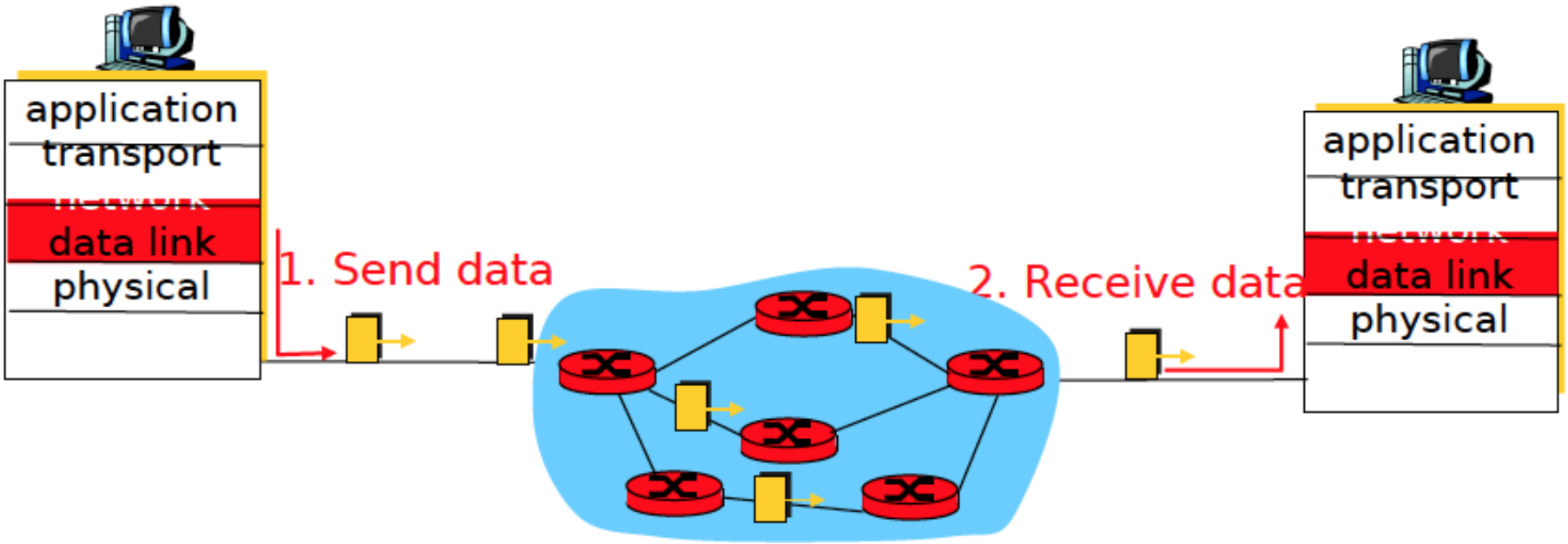
- performance-wise
- network actions along source-to-dest path

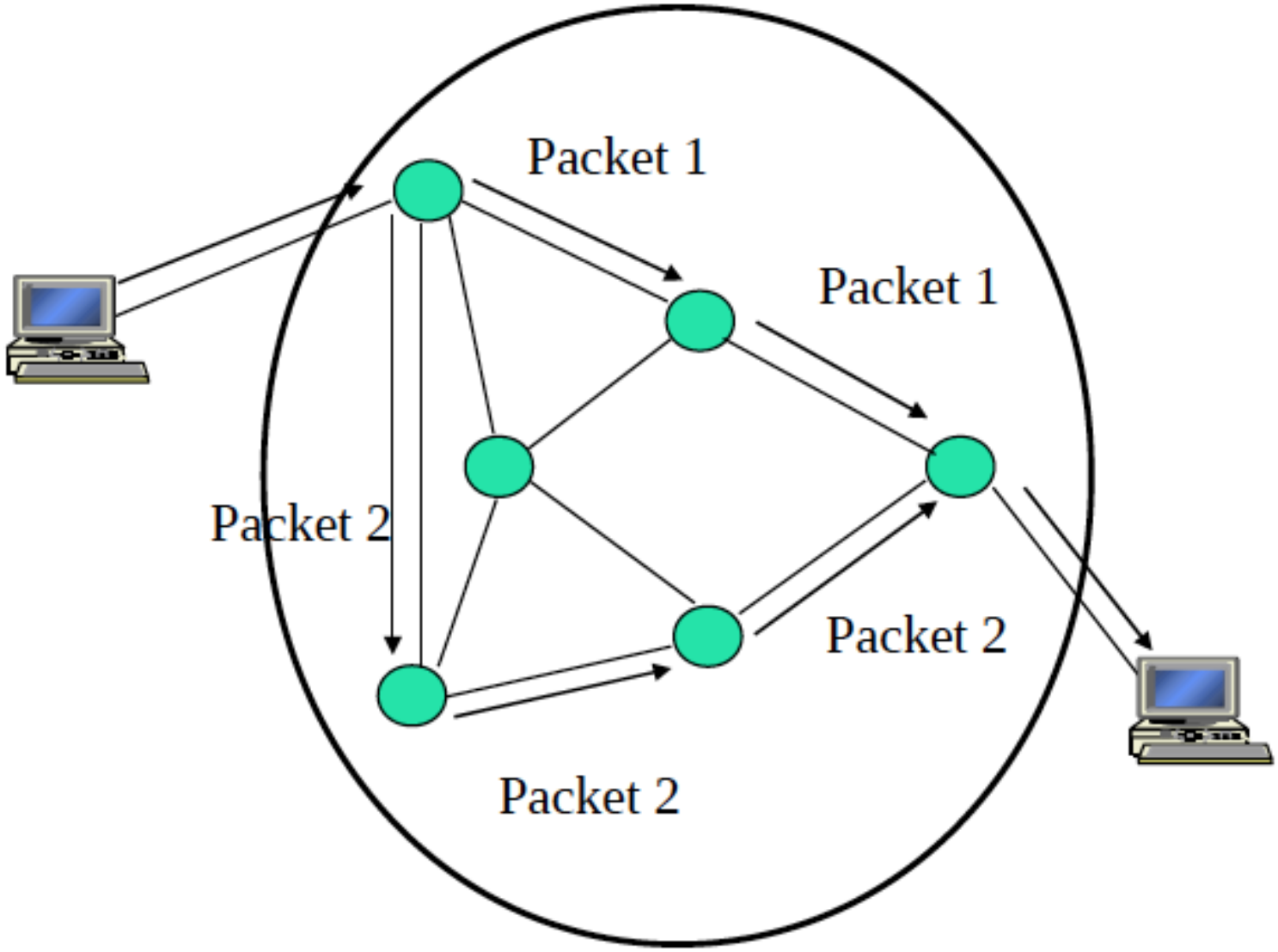


- call setup, teardown for each call *before* data can flow
- each packet carries VC identifier (not destination host address)
- routers on source-dest path maintains "state" for each passing connection
- link, router resources (bandwidth, buffers) may be *allocated* to VC

Connectionless (Datagram Networks)

- no call setup at network layer
- routers: do not maintain state for e2e connections
  - no network-level concept of “connection”
- packets forwarded using destination host address
  - packets between the same source-dest pair may take different paths




Packet 1
Packet 1
Packet 2
Packet 2
Packet 2

Routing

- ***Routing algorithm*** **:** Part of the Network Layer responsible for deciding on which output line to transmit an incoming packet.
  - Remember: For virtual circuit subnets the routing decision is made ONLY at setup

- **Algorithm properties**:
  - Efficiency, correctness, simplicity, robustness, stability, fairness, optimality, and scalability

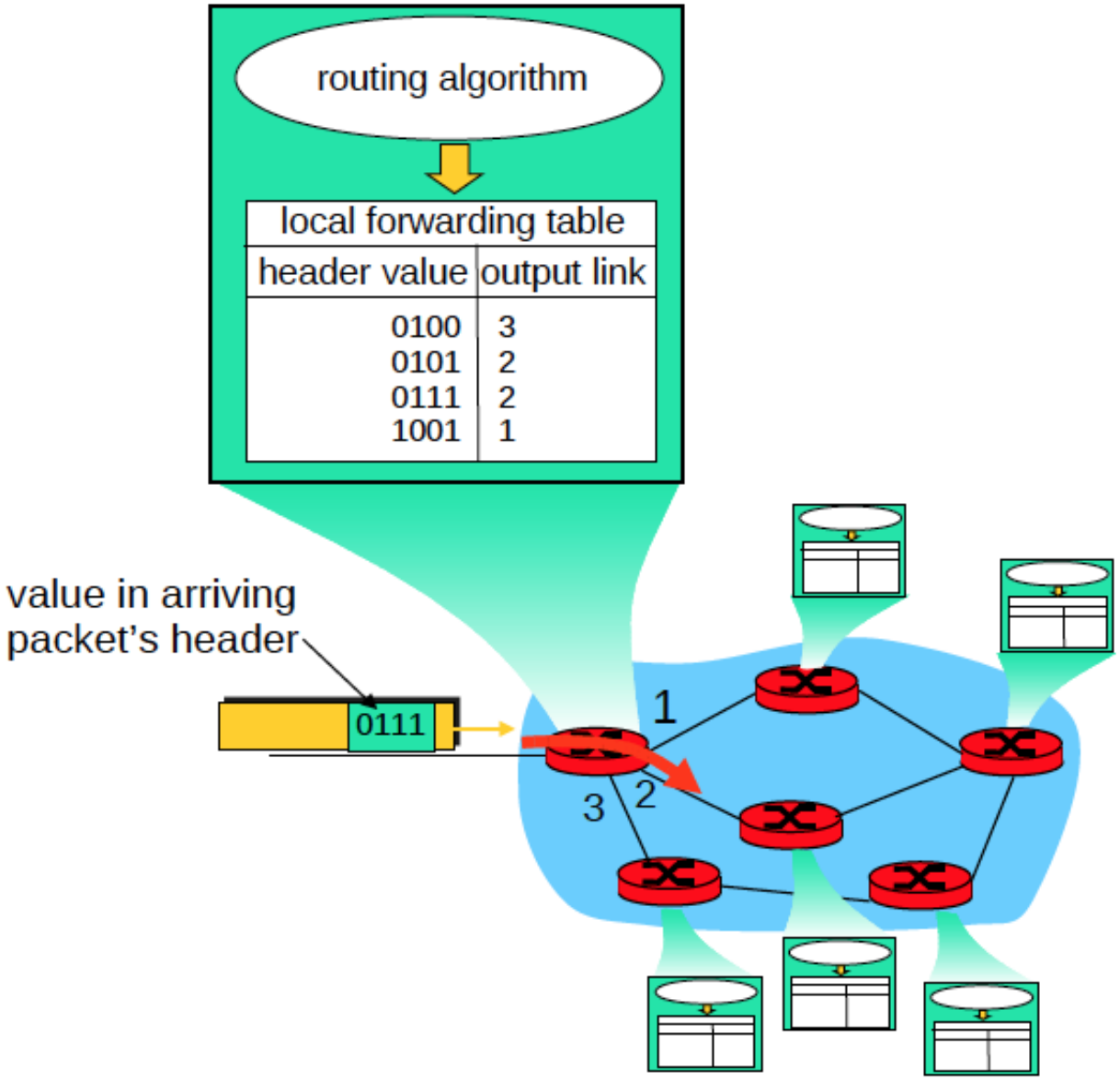
Key Network-Layer Functions

- *routing:* determine route taken by packets from source to dest
- *forwarding:* move packets from router's input to appropriate router output

Analogy:

- *routing:* process of planning trip from source to dest
- *forwarding:* process of getting through single interchange

Relation Between Forwarding and Routing



Routing Table

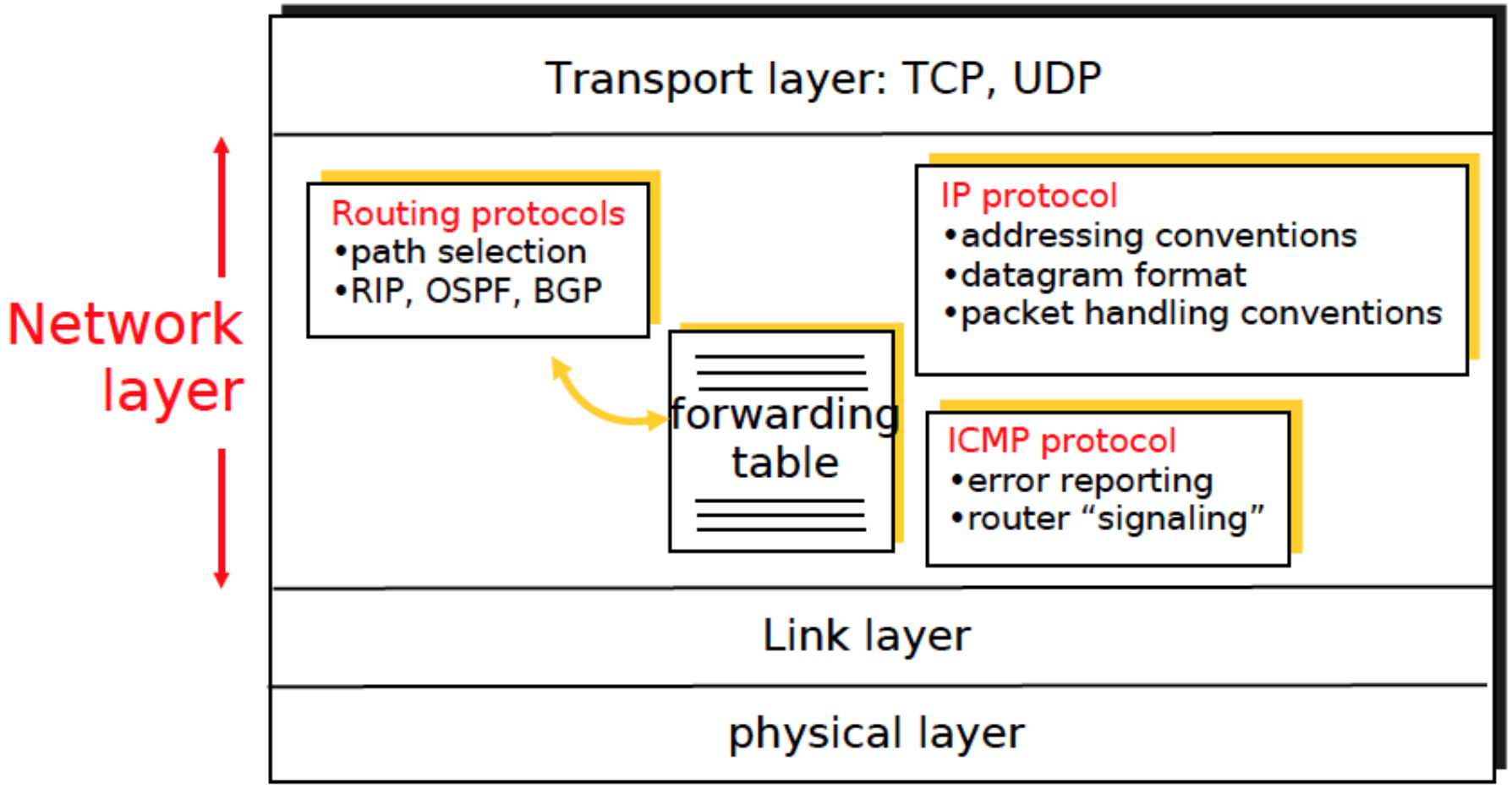
Destination address	Output port
0785	7
1345	12
1566	6
2458	12

Elements of Routing Techniques

- Performance criteria: Used for selection of routes
  - # of hops, cost, delay, throughput
- Decision Place:
  - Distributed (each node)/Centralized/Source routing
- Decision Time: Packet or VC basis
- Network Information Source:
  - None, local, adjacent node, all nodes
- Network Information Update:
  - Continuous, periodical, on change

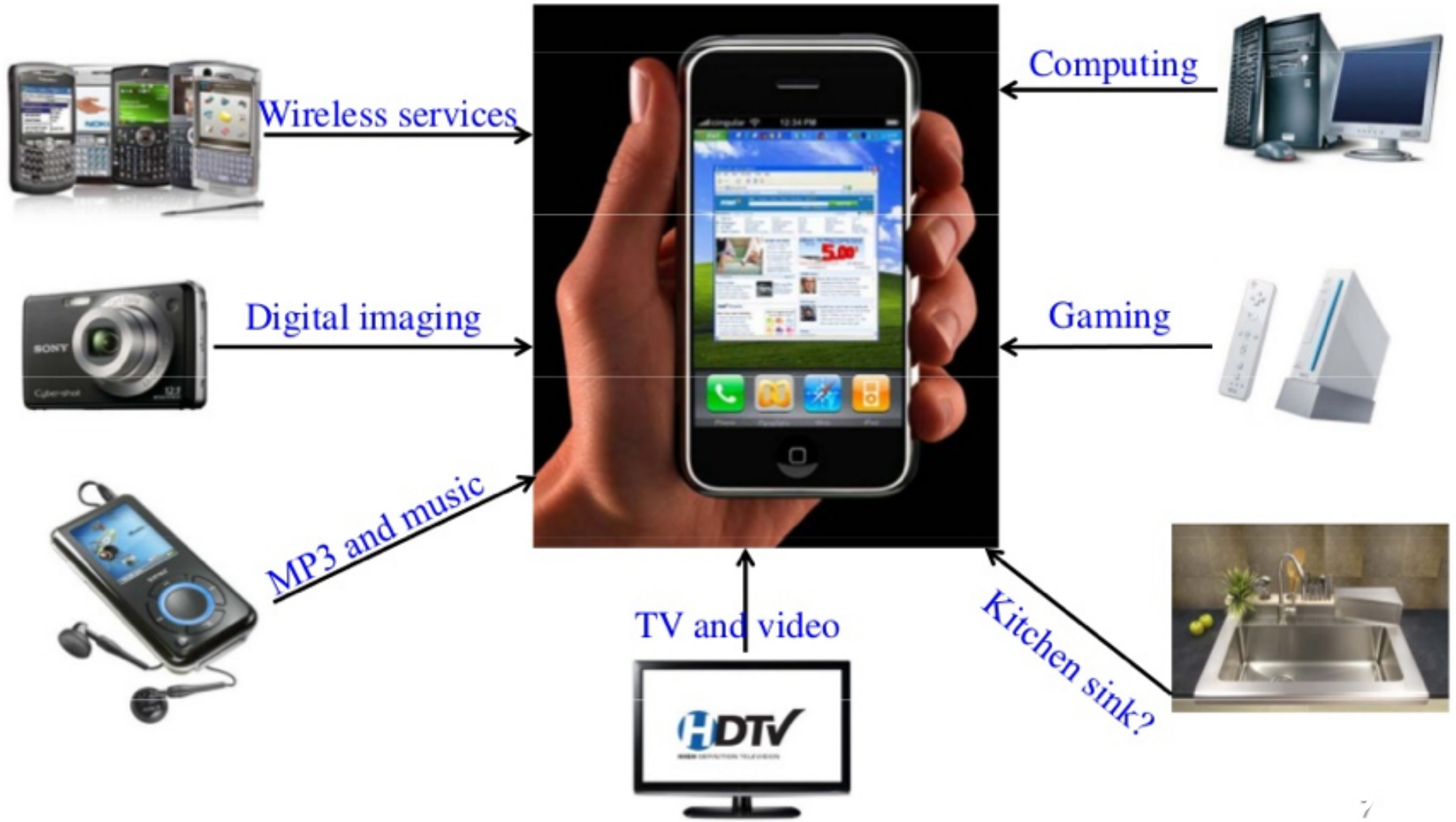
The Internet Network layer

Host, router network layer functions:

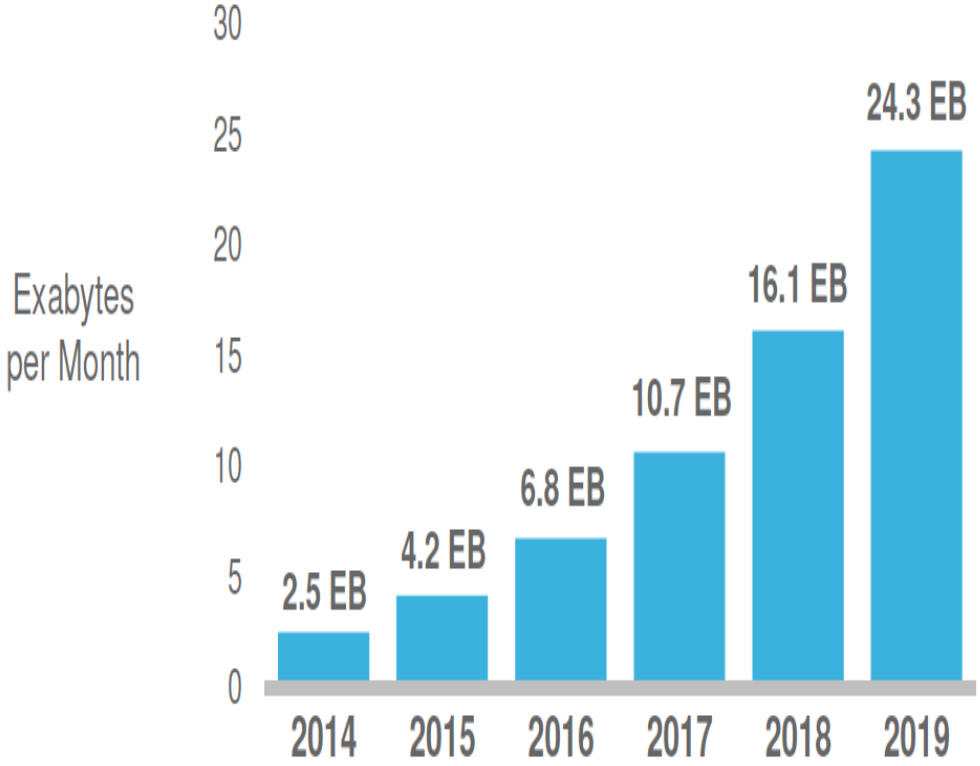


-Next Generation Wireless Networks-

Technology Convergence..



Some Motivations: Growth of Internet DataTraffic

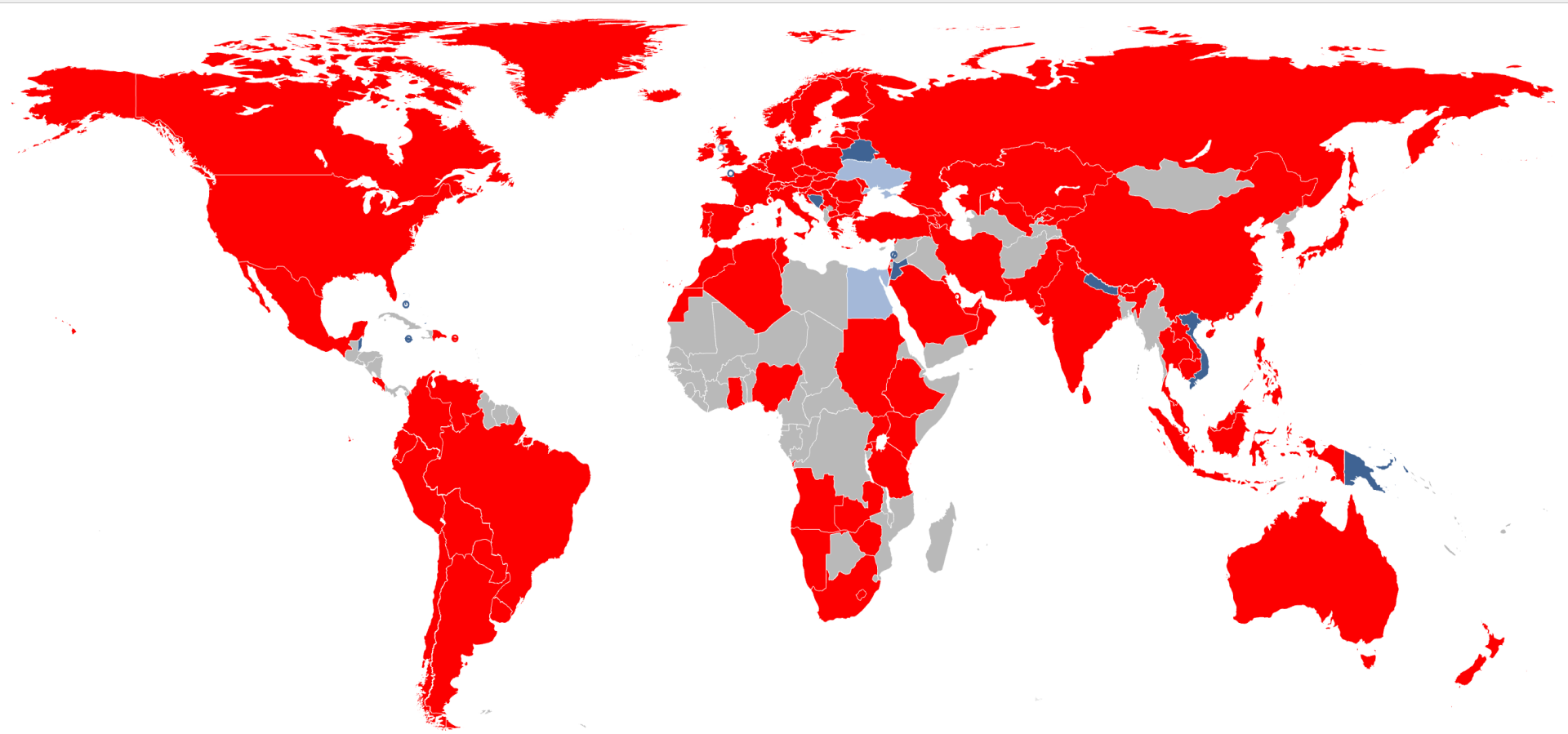


- In 2015, wireless devices accounted for the **48%** of IP traffic.
- **Traffic from wireless and mobile devices will account for two-thirds of total IP traffic by 2020.**
- Mobile data traffic will increase **eightfold** between 2015 and 2020.

Source: Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2014–2019.

Countries with Commercial LTE Service

Date: Dec 2016



Countries with commercial LTE Service

Countries with commercial LTE Network Deployment ongoing or planned

Countries and regions with LTE trial systems (pre-commitment)

Source: https://en.wikipedia.org/wiki/LTE_(telecommunication)

Some Coverage Maps: 2G/3G Turkey

Date: Dec 05, 2017

Source: OpenSignal, https://opensignal.com/networks/

Some Coverage Maps: 4G Turkey

Date: Dec 05, 2017

Source: OpenSignal, https://opensignal.com/networks/

Current Situation in Networking Usage..

In one hour, around the globe;

- 750 million SMS messages
- 148 million Google searches
- 10 million tweets
- 1.3 million mobile apps downloaded
- 3180 hours of Youtube videos uploaded
- 50000 smart phones activated

Nokia-Siemens Network and Cisco Crp., 2017

So how to handle this?

We need Innovative network designs!!!

One effective solution→ **Group, Cluster, Classify wireless users according to**

--Their geographic positions (indoor,outdoor, rural, urban, airport, malls, streets etc..)

--Their traffic usage (Data, Voice, Video, etc)

--Their Types of wireless technology they use (3G, 4G, WiFi, Bluetooth etc)

Mobile Network Technology Evolution

- 1989
  - GSM Radio Access Network (2G)
- 1998
  - GSM EDGE integration (2.5G- 2.75G)
- 1999
  - UMTS, HSxPA Terrestrial Radio Access Network (3G)
- 2004
  - 4G (LTE)
- 2011
  - LTE-Advanced
- Non 3GPP
  - Wifi (IEEE 802.11x, 1991-1999)
  - WiMAX (IEEE 802.16x, (2005)

LTE and LTE-Advanced

- Long Term Evolution (LTE) is the latest step in moving forward from the cellular 3G services
- LTE is based on standards developed by the 3rd Generation Partnership Project (3GPP).
- LTE and LTE – Advanced may also be referred more formally as Evolved UMTS Terrestrial Radio Access (E-UTRA) and Evolved UMTS Terrestrial Radio Access Network (E-UTRAN).

What is a Small Cell?

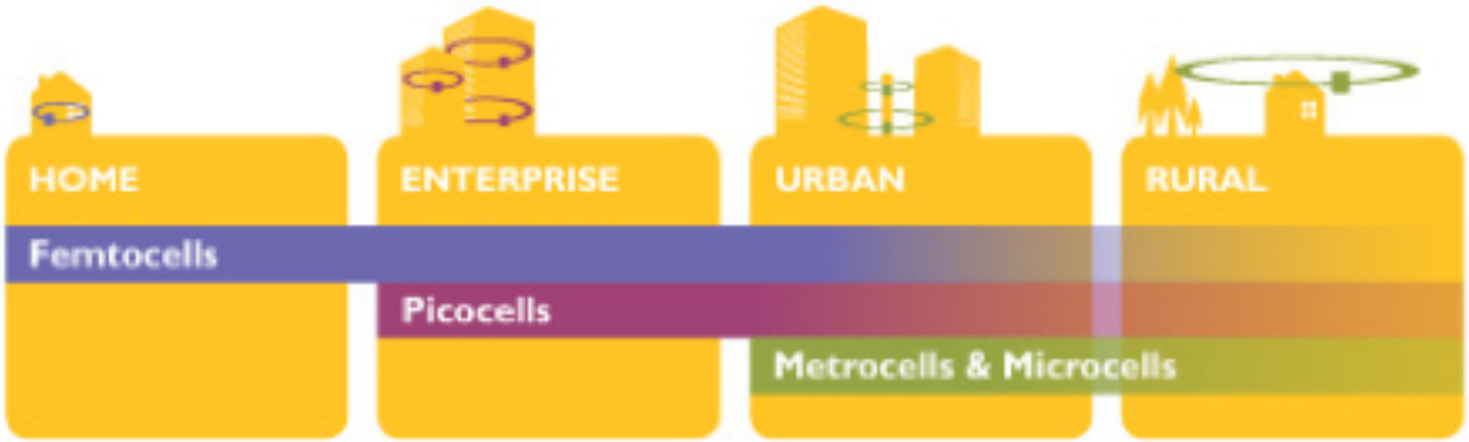
- Small cells are low-power wireless access points that operate in licensed spectrum.
- They are operator-managed.
- They are features in an edge-based intelligence.

Different types of Small Cells

According to their coverage:

From Macro to Femto..

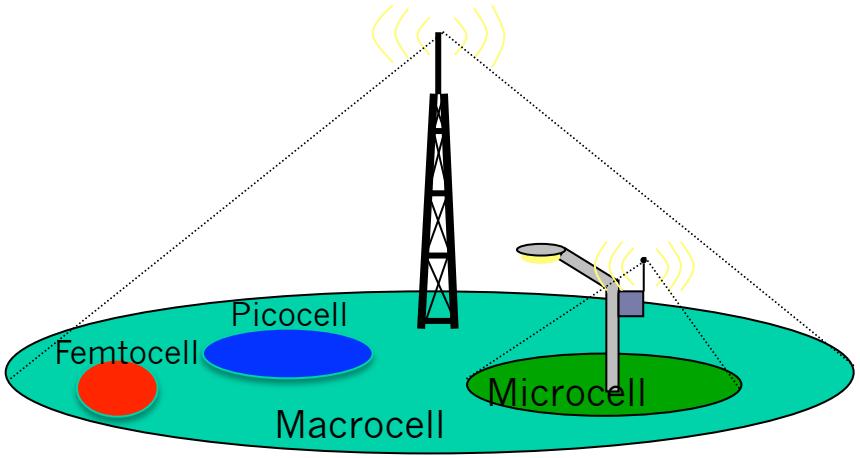
-Metrocells
-Microcells
-Picocells
-Femtocells



http://www.smallcellforum.org/

Clustering the “cells”..

- **Macrocell→ 10 km**
- **Microcell→ 2 km (dedicated backhauls since deployed by operators)**
- **Picocell→ 200 m (16-32 users)** (dedicated backhauls since deployed by operators)
- **Femtocell→10 m (4-8 users)** (poped-up by users, connected to operators through DSL/ Cable/Ethernet)

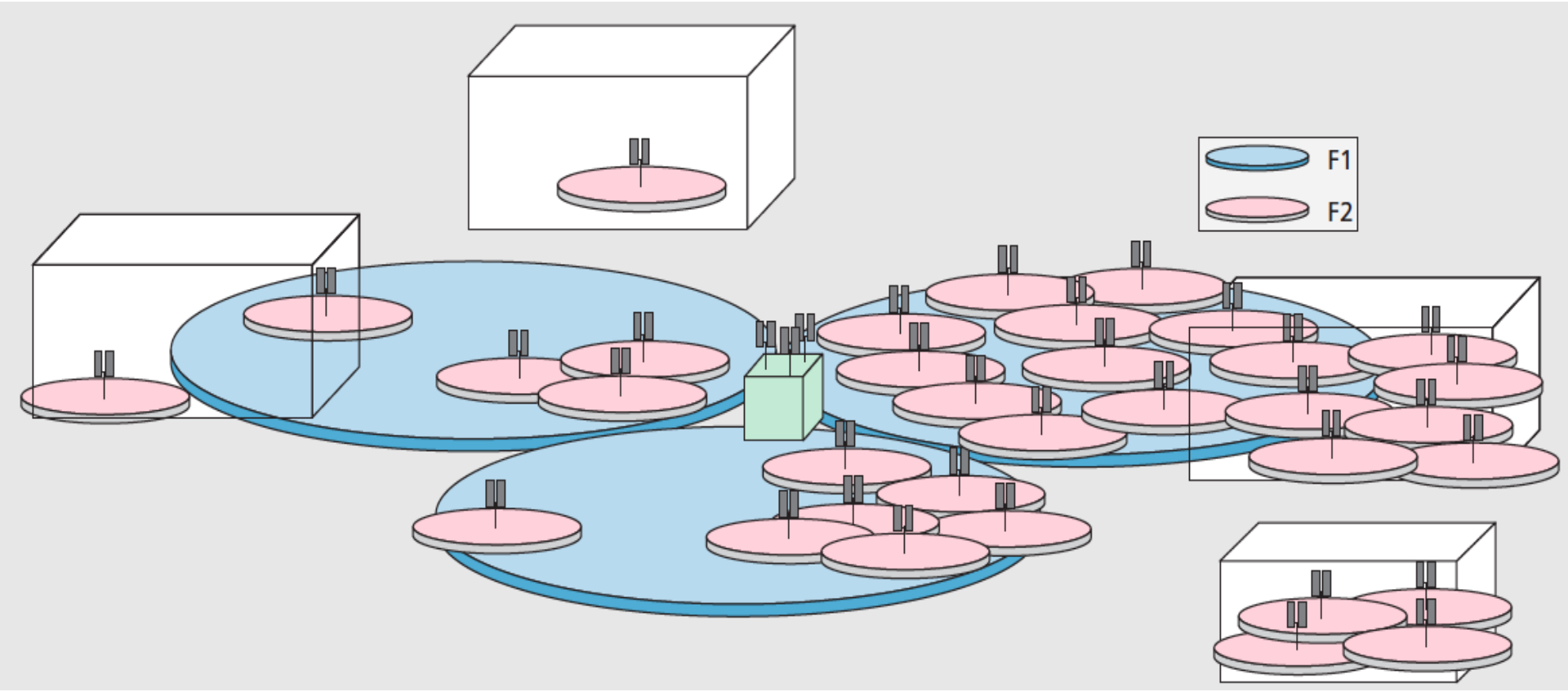


Standards

- 3GPP (3rd Generation Partnership Project
  - Version 8, 2009→ 3G Home NodeB

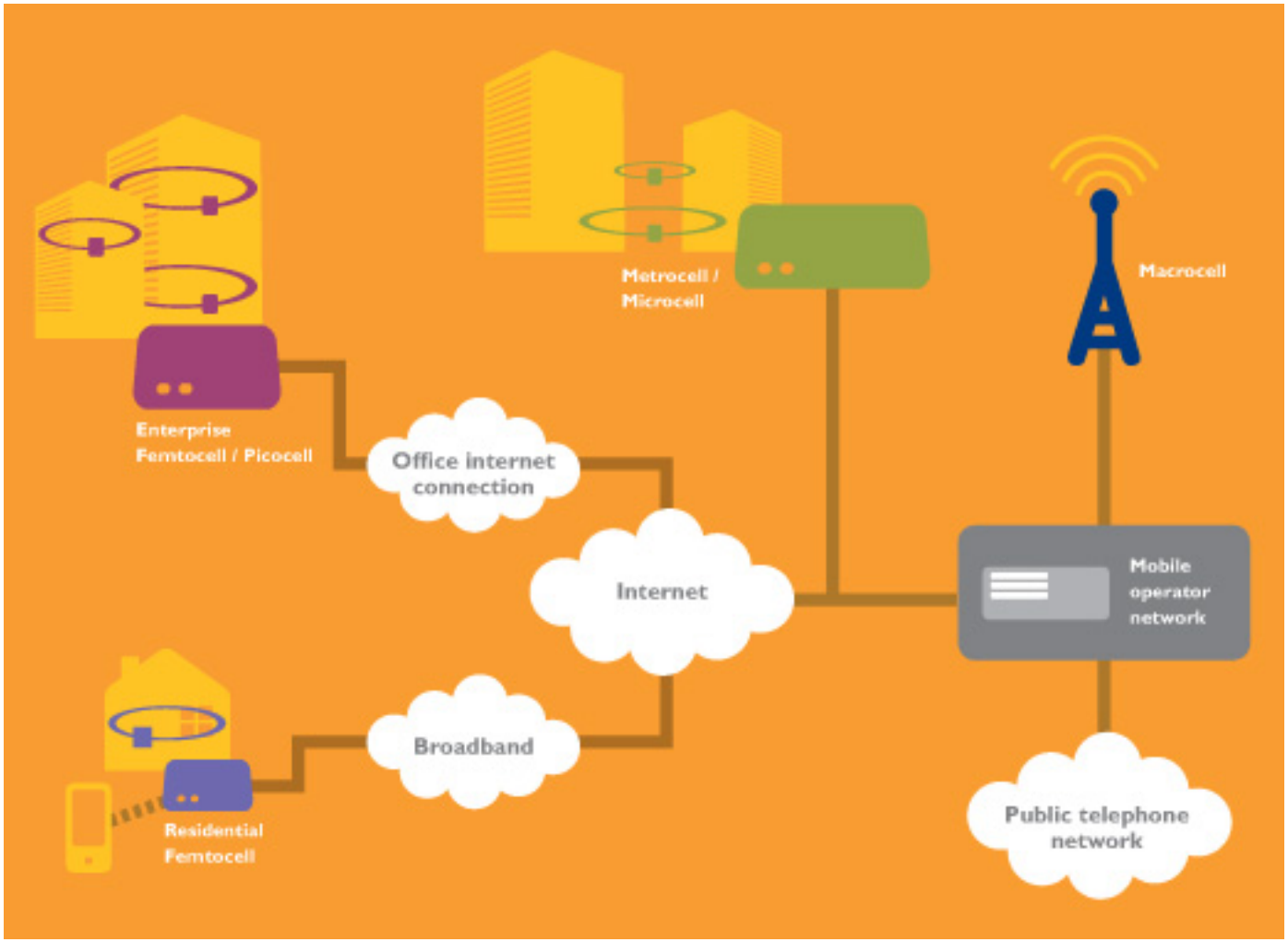
- Small Cell Forum (Femto Forum)
  - 2007
  - 16 technology companies (Alcatel-Lucent, AT-T, Cisco, Ericsson,Nokia, Vodafone, ..)
  - http://www.smallcellforum.org/

Outdoor Deployment-1



T.Nakamura et al., ‘‘Trends in Small Cell Enhancements in LTE Advanced’’, IEEE Communications Magazine, Feb.2013.

Outdoor Deployment-2



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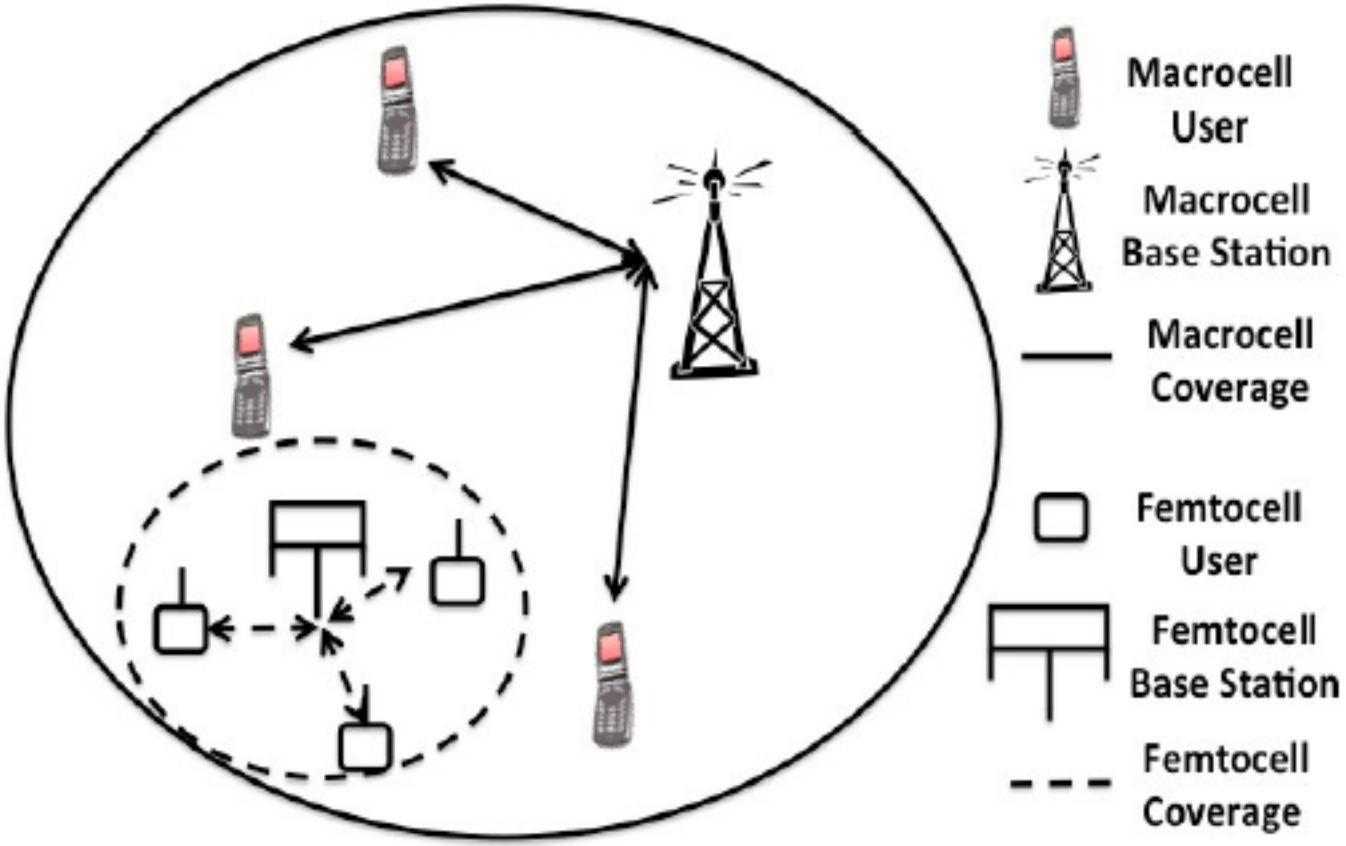
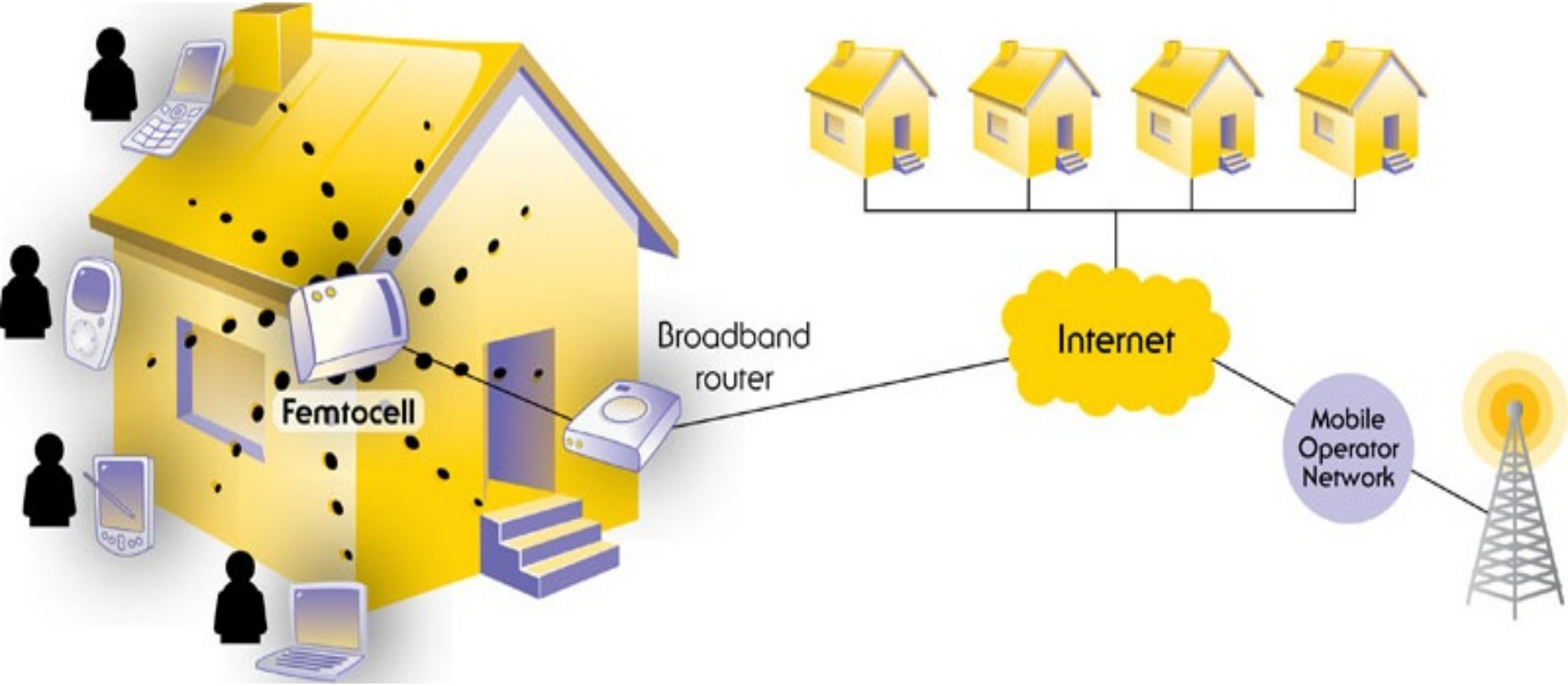
Indoor Deployment-1



Gutierrez-Estevez, D. M., Canberk, B., and Akyildiz, I. F., "Spatio-Temporal Estimation for Interference Management in Femtocell Networks," in Proc. of IEEE PIMRC, Sidney, Australia, September 2012.

Indoor Deployment-2



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