Le reti dei calcolatori

Slides are mainly taken from

- *W.R. Stevens "Unix Network Programming" Prentice Hall, 1999*
- *Peterson – Davie "Computer Networks: A system approach" Morgan Kaufmann 2000*
- *Andrew Tanenbaum and David Wetherall, "Computer Networks"*
- *William Stallings "Operating Systems: Internals and Design Principles", 8/E (Chapter 5).*

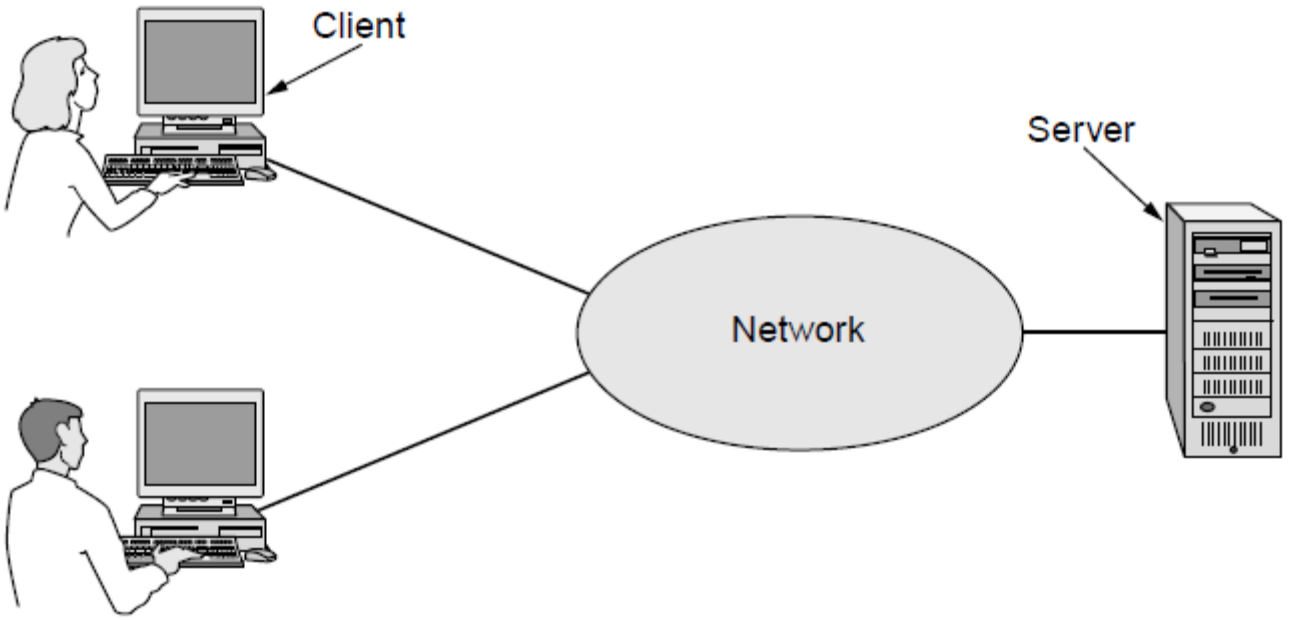
Sistemi di Calcolo 2

Instructor: Riccardo Lazzeretti

Special thanks to: Daniele Cono D'Elia, Leonardo Aniello, Roberto Baldoni

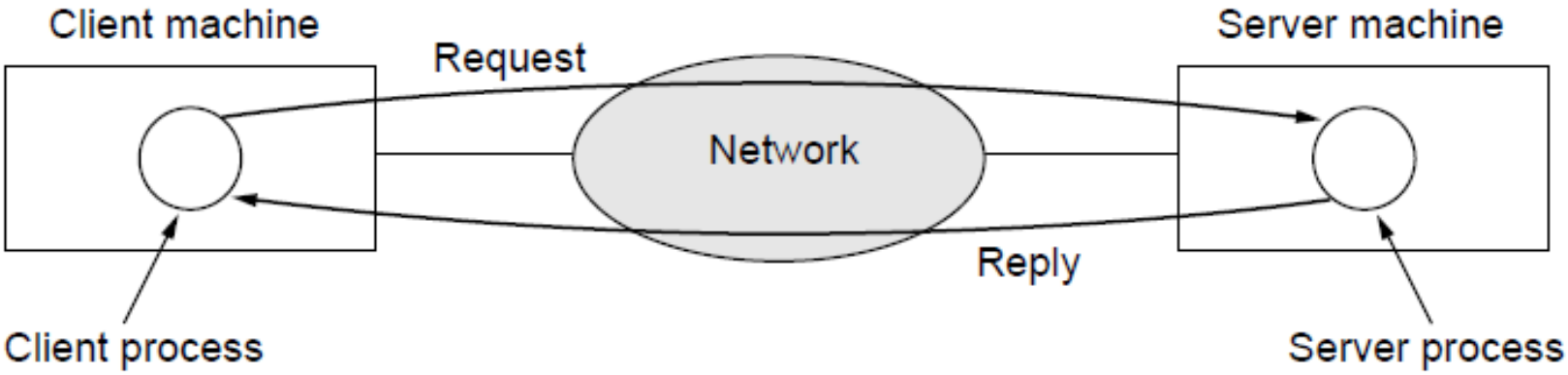
Architettura di Internet

Business Applications (1)

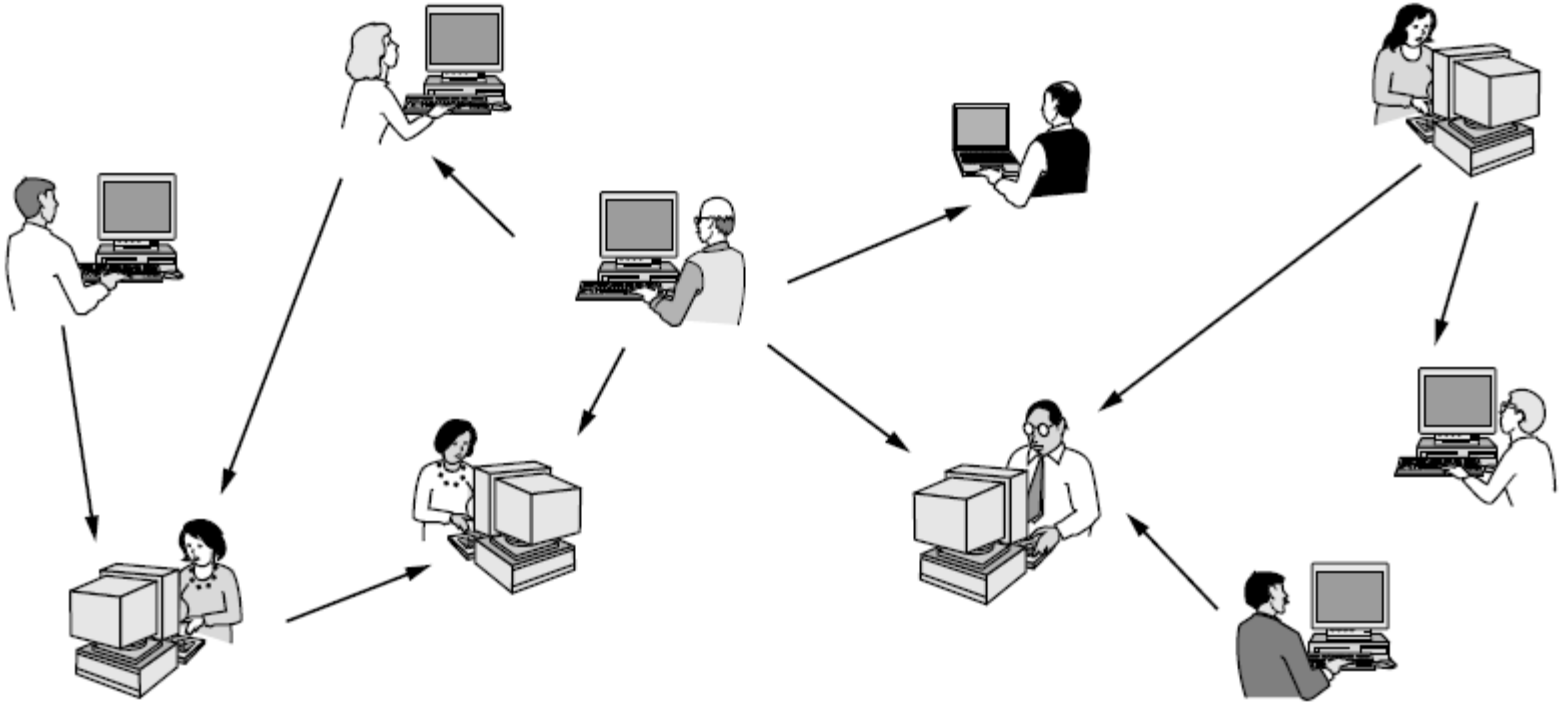


Business Applications (2)

The client-server model involves requests and replies



Home Applications

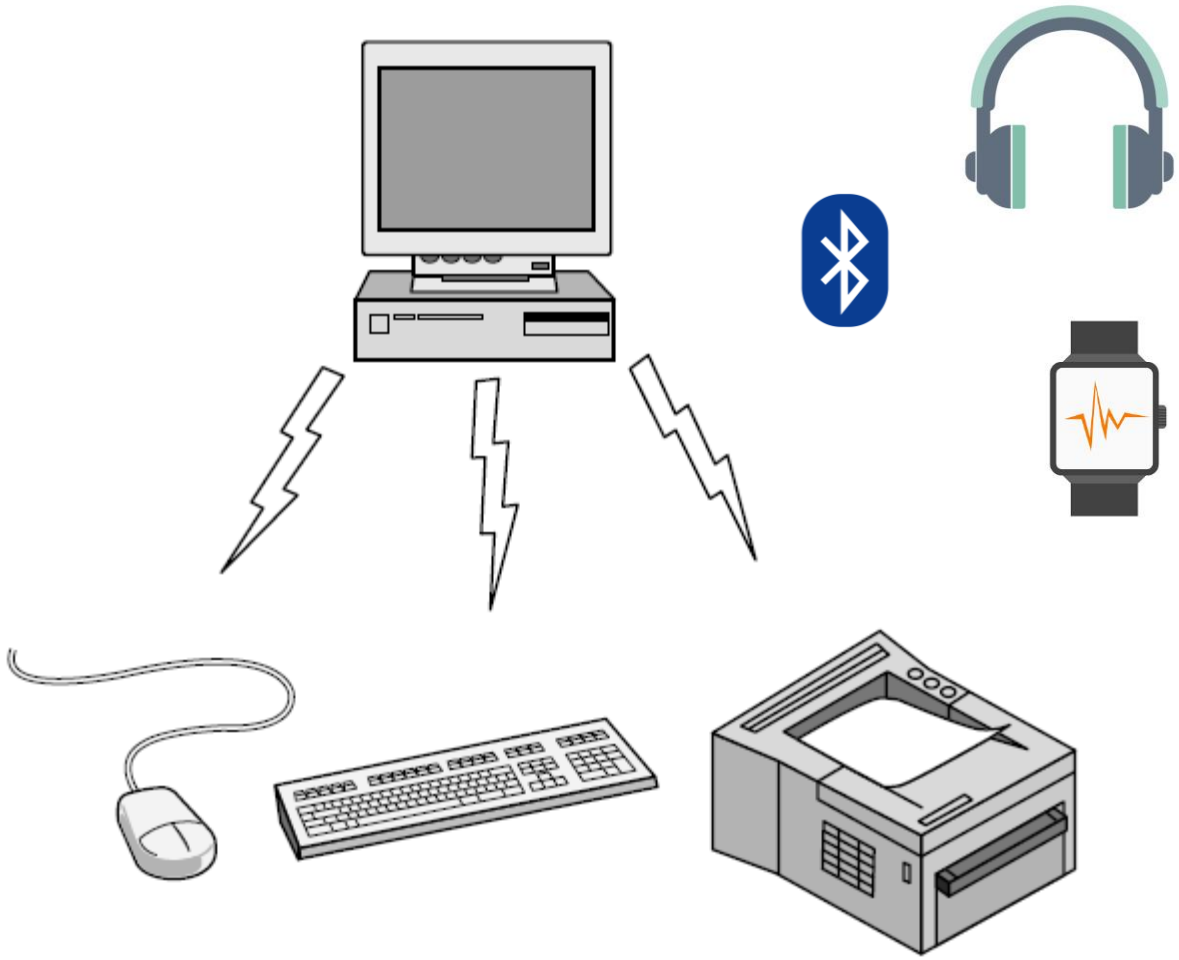


In a peer-to-peer system there are no fixed clients and servers.

Network classification by scale

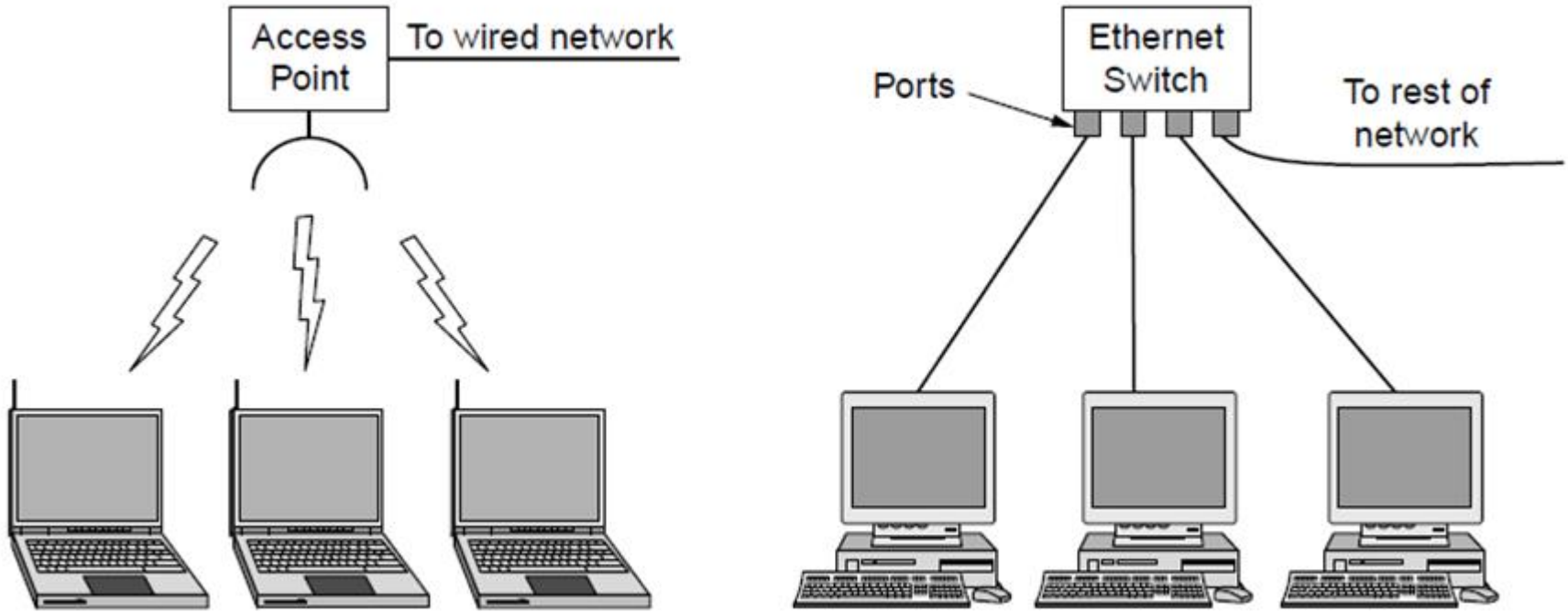
Interprocessor distance	Processors located in same	Example
1 m	Square meter	Personal area network
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1000 km	Continent	
10,000 km	Planet	The Internet

Personal Area Network



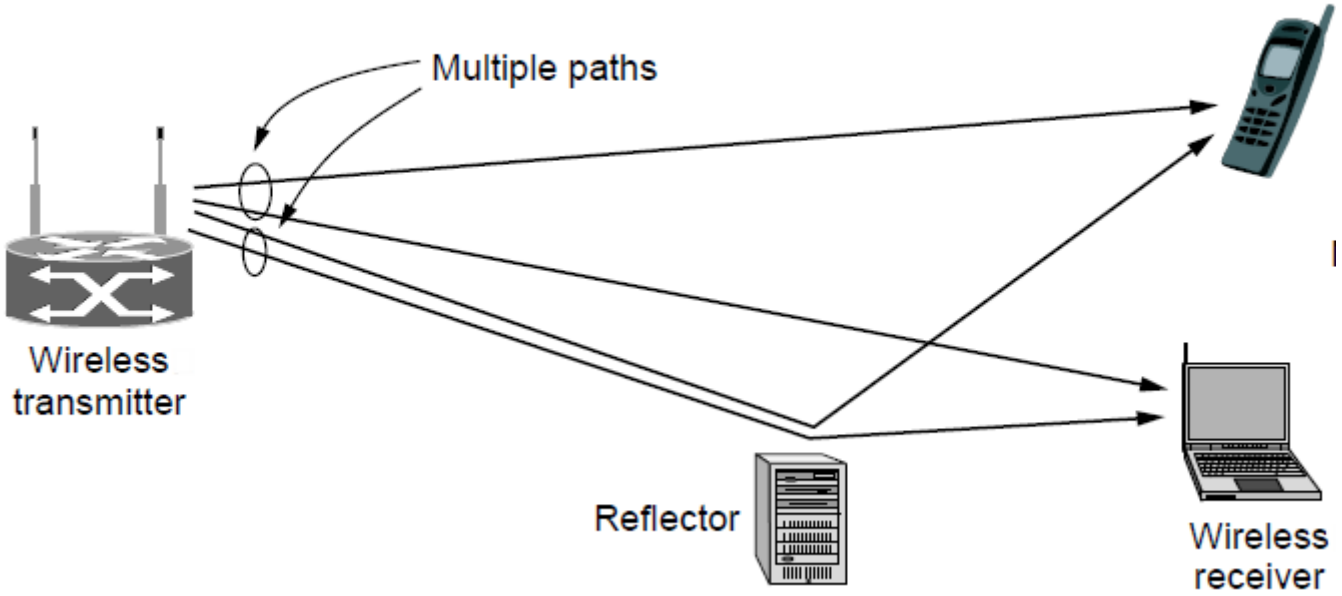
Local Area Networks

Wireless and wired LANs. (a) 802.11. (b) Switched Ethernet.

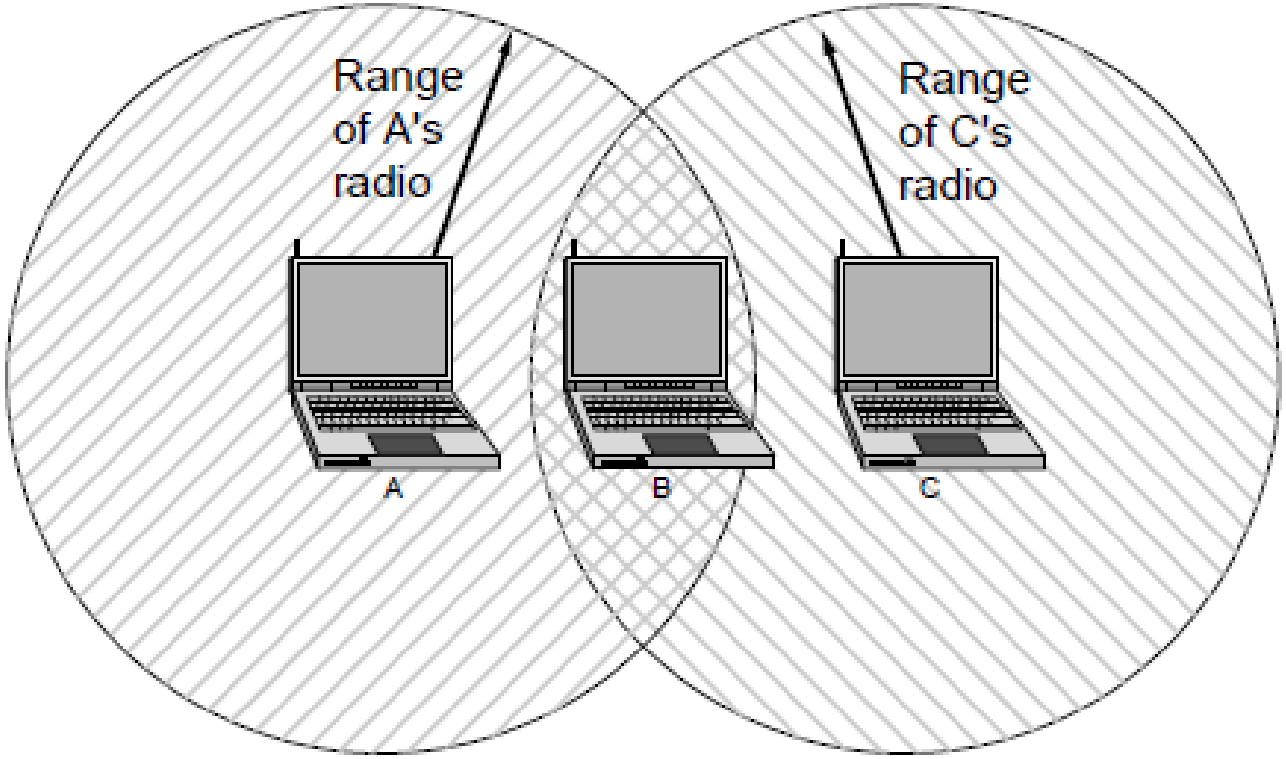


Wireless LANs: 802.11 (2)

Multipath fading

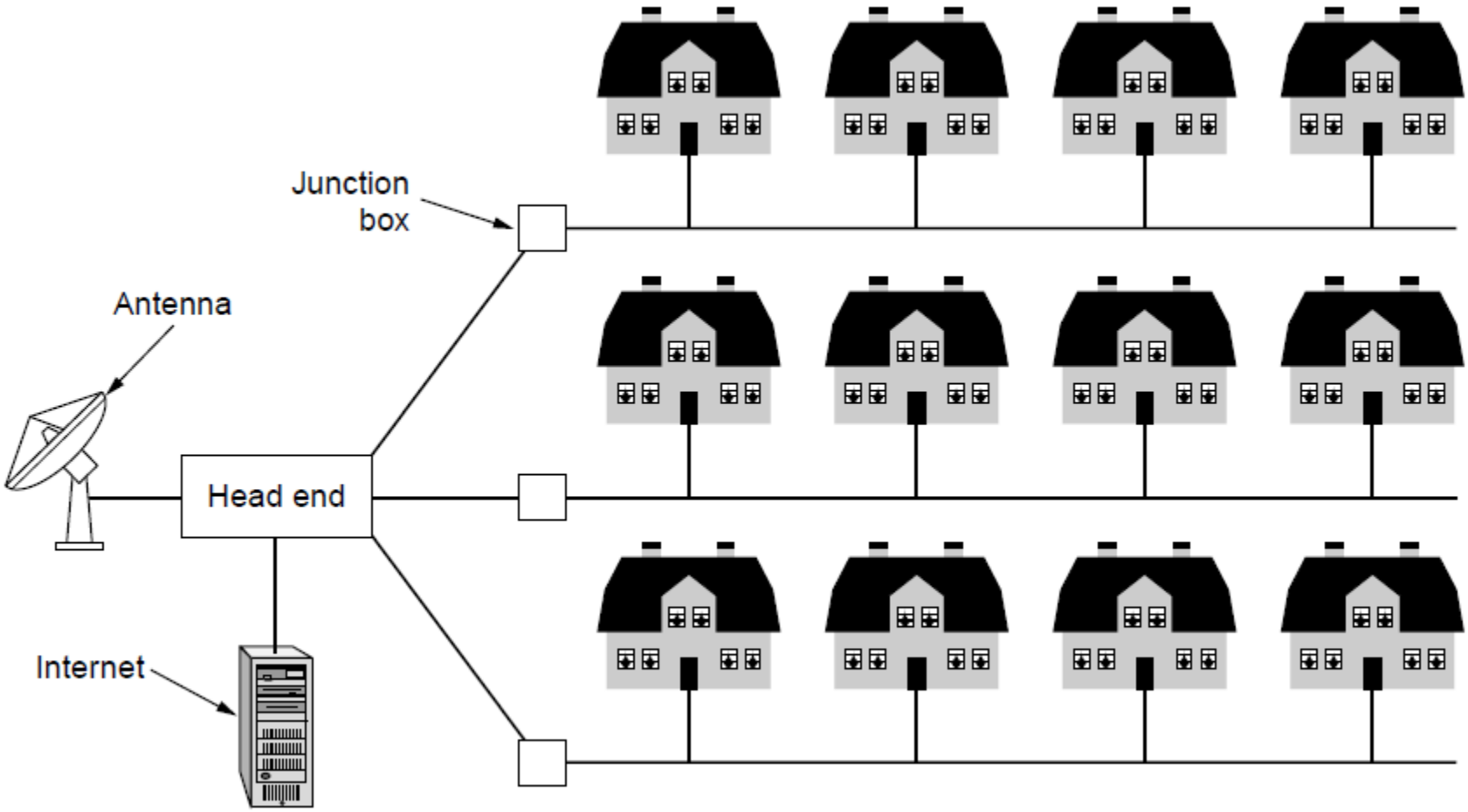


Wireless LANs: 802.11 (3)



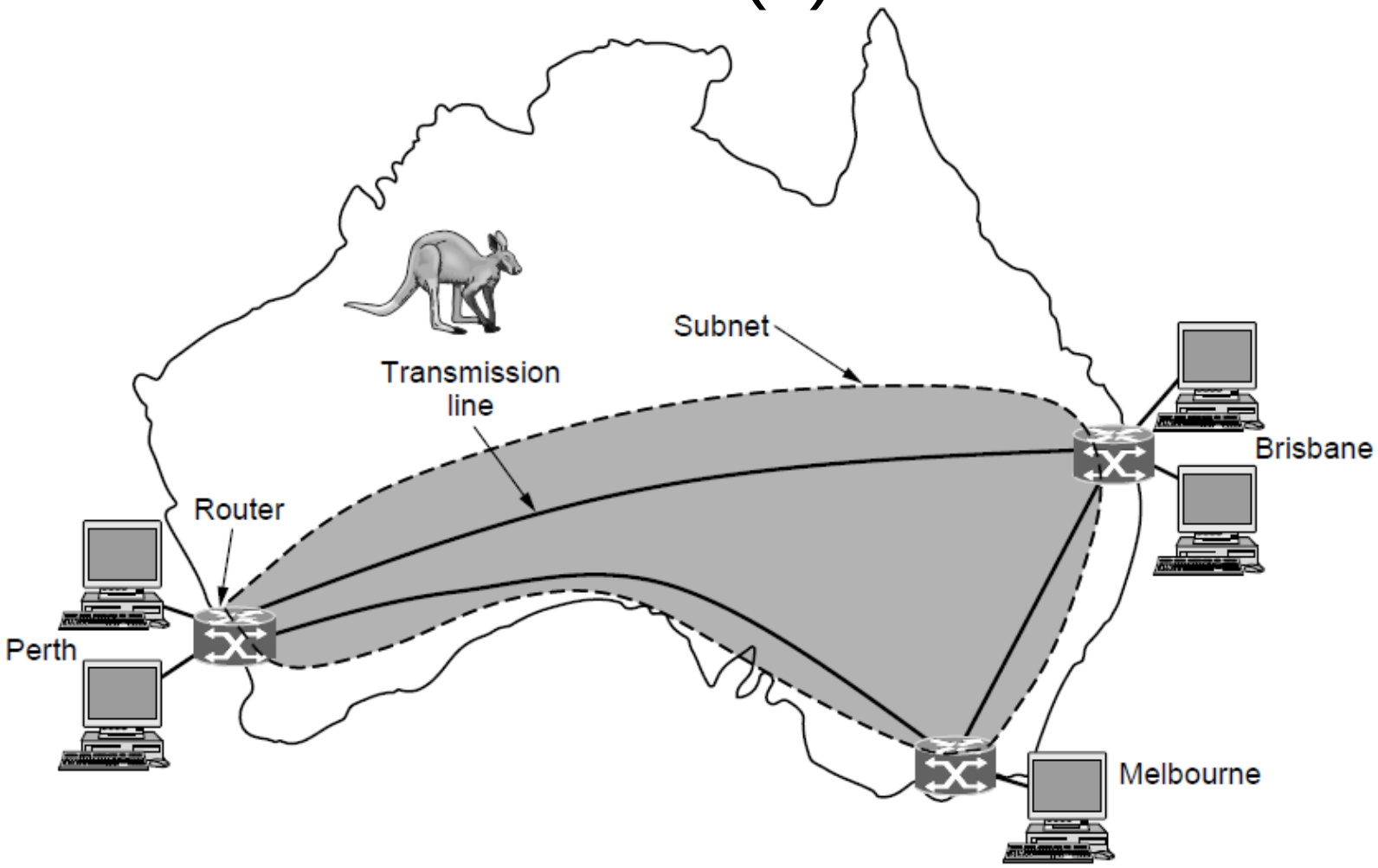
The range of a single radio may not cover the entire system.

Metropolitan Area Networks



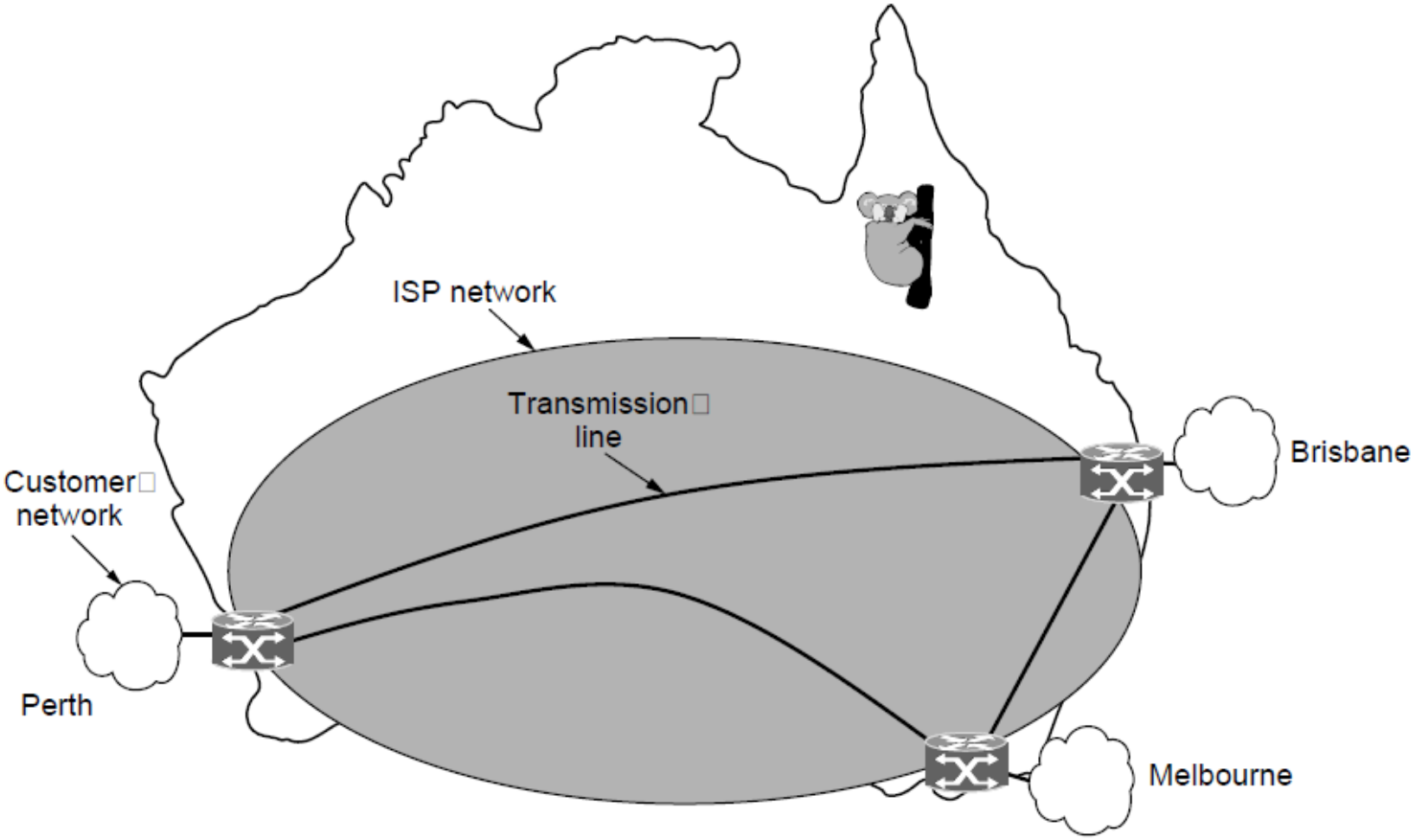
A metropolitan area network based on cable TV.

Wide Area Networks (1)



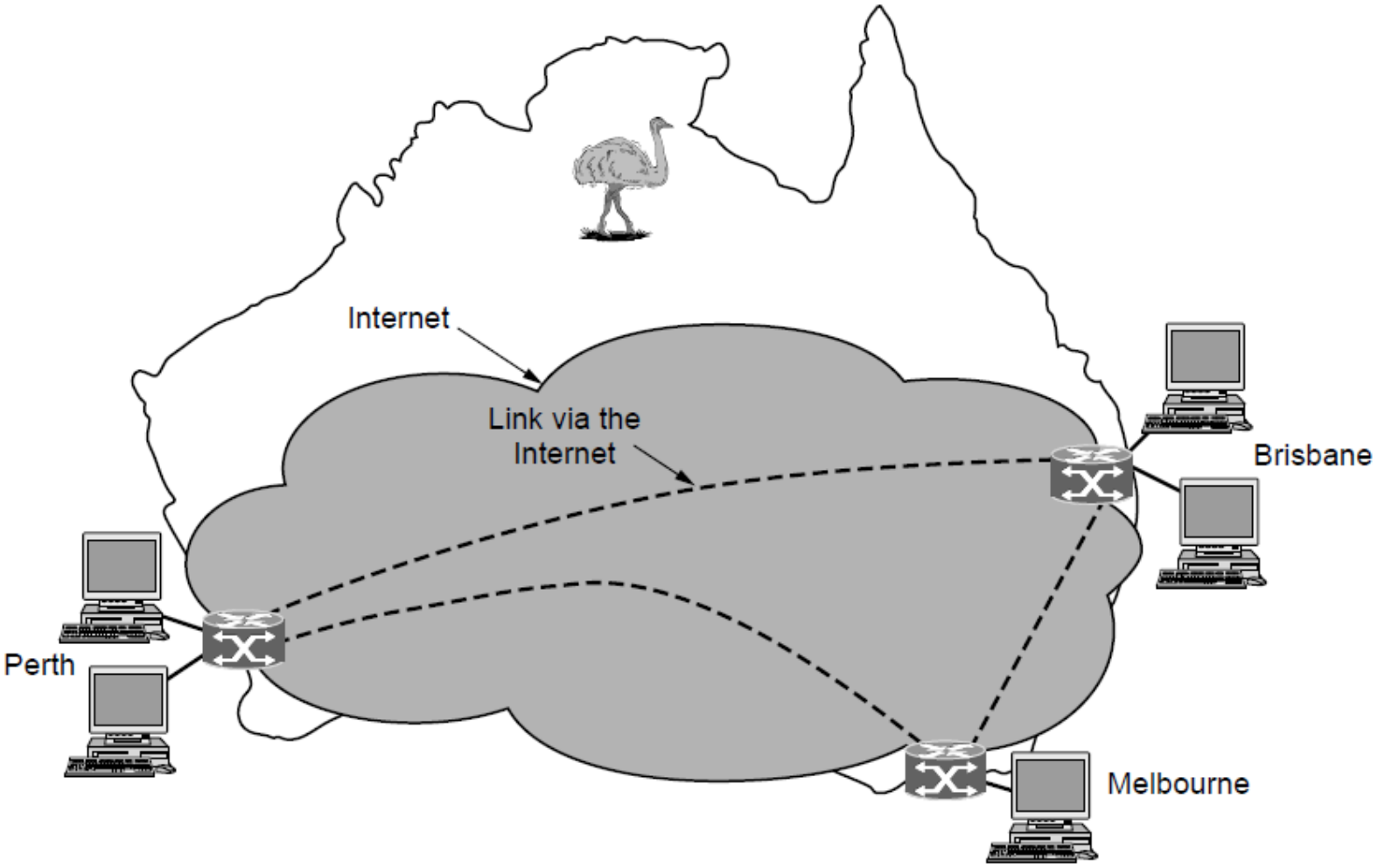
WAN that connects three branch offices in Australia

Wide Area Networks (2)



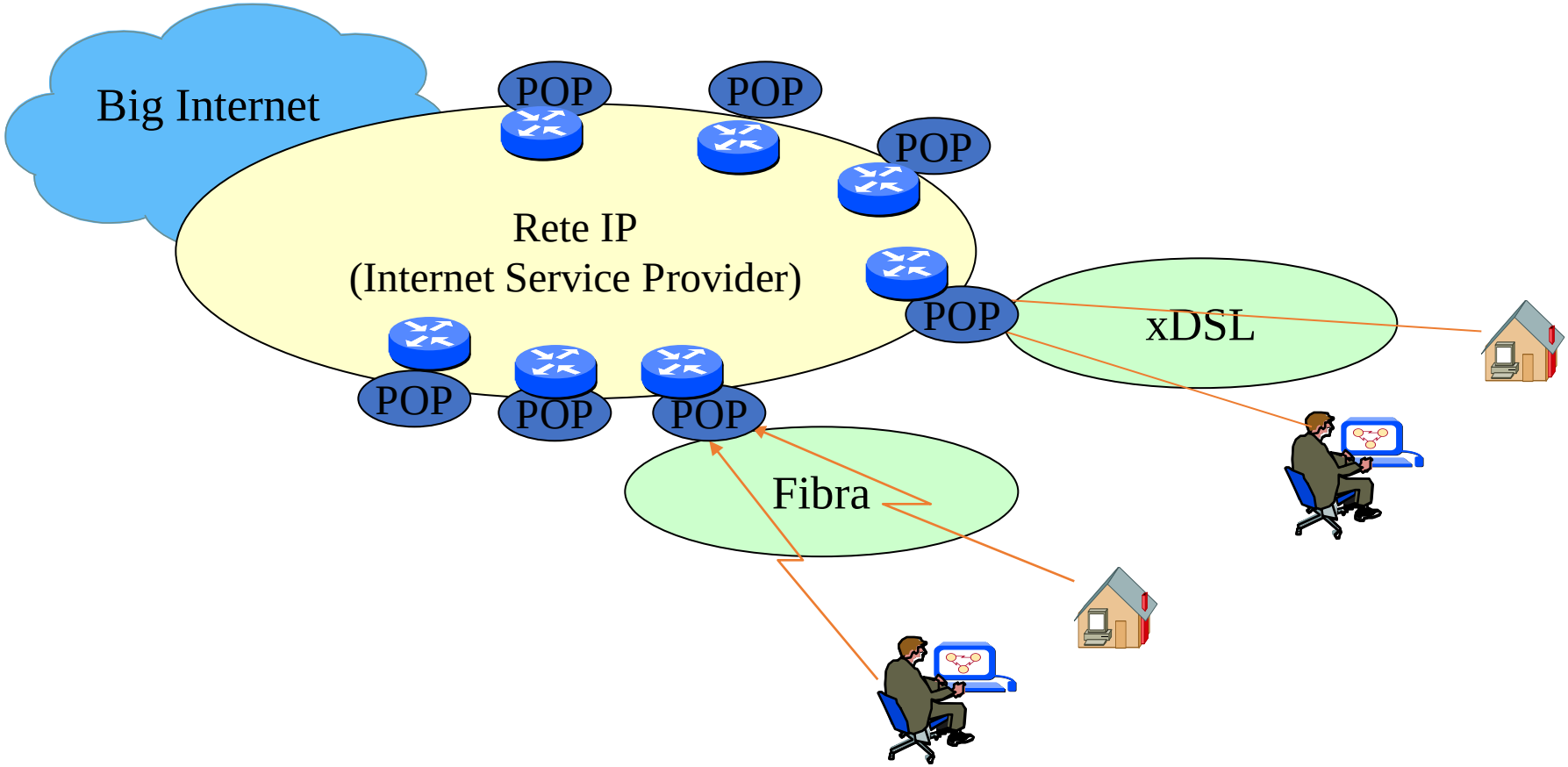
WAN using an ISP network.

Wide Area Networks (3)

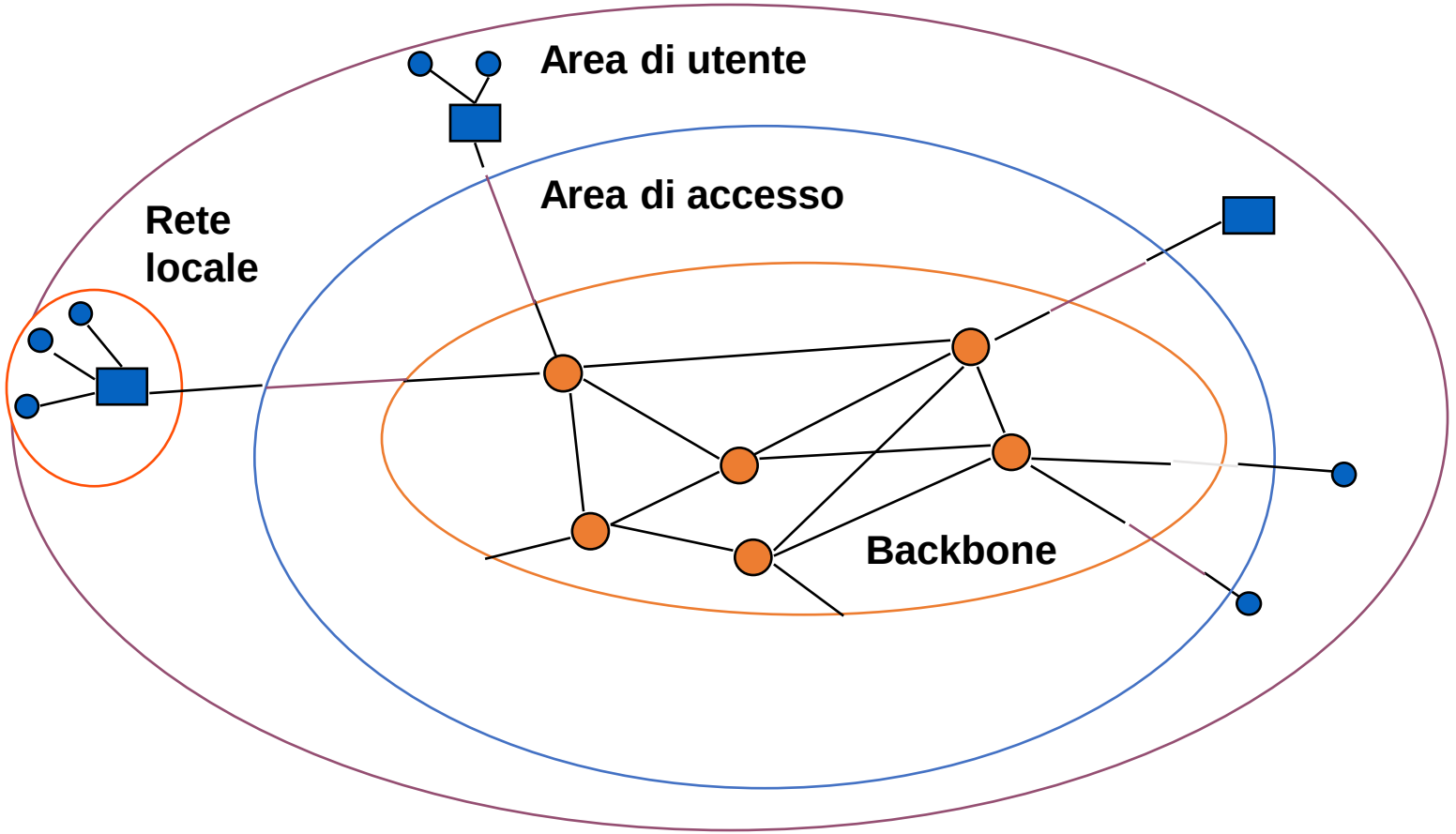


WAN using a virtual private network.

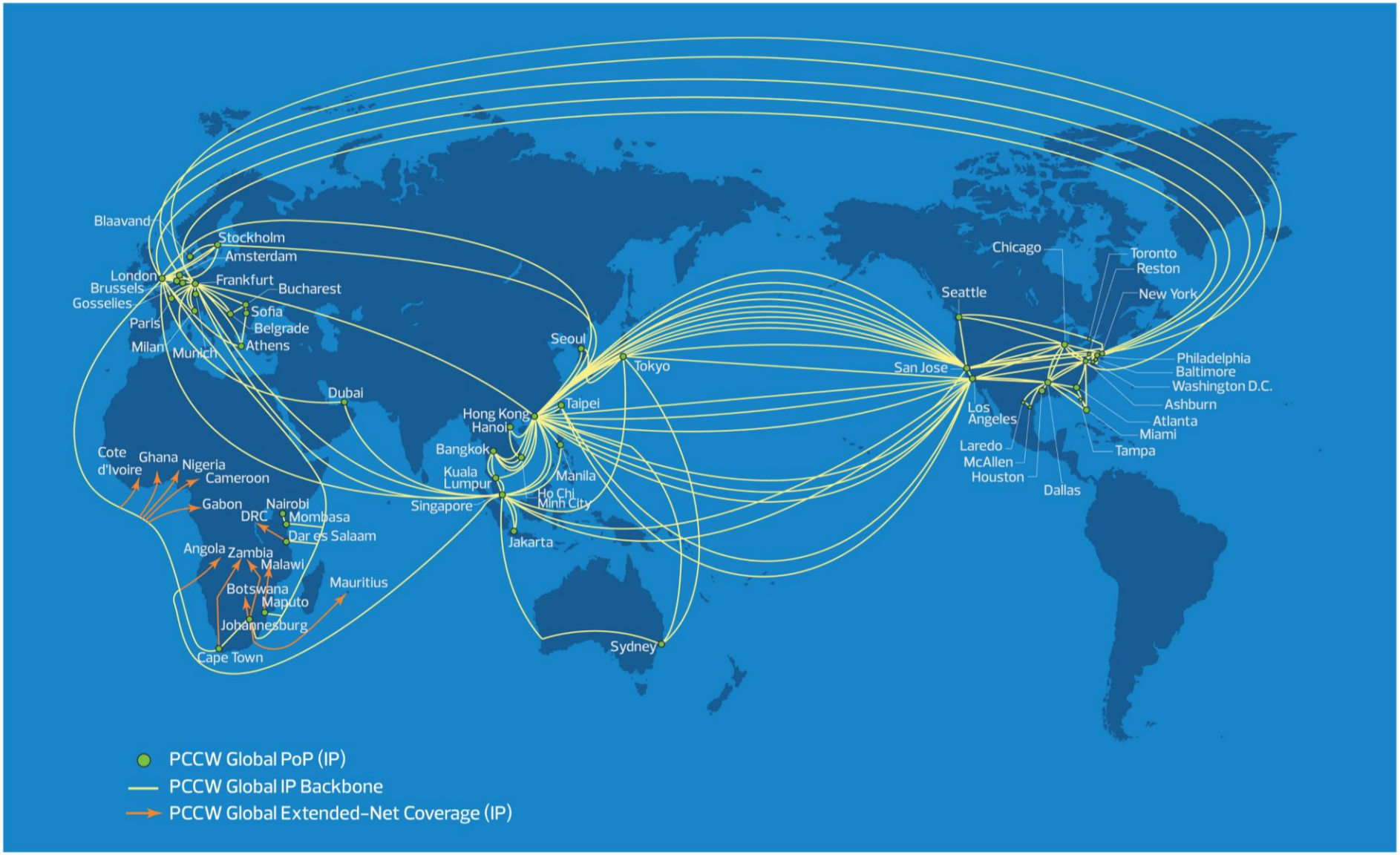
Internet Service Providers



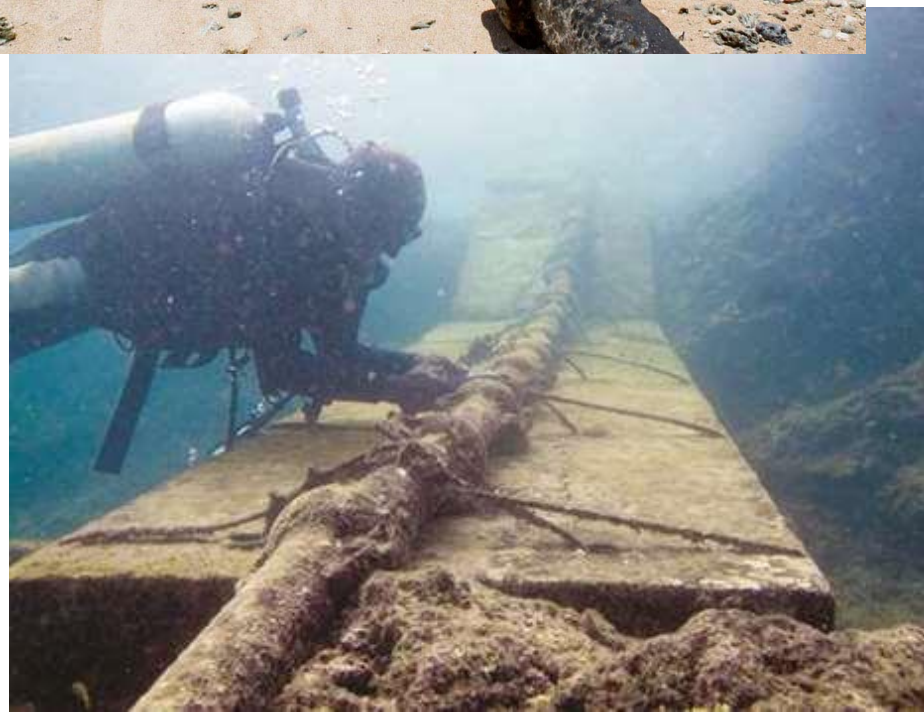
Rete geografica per trasmissione dati

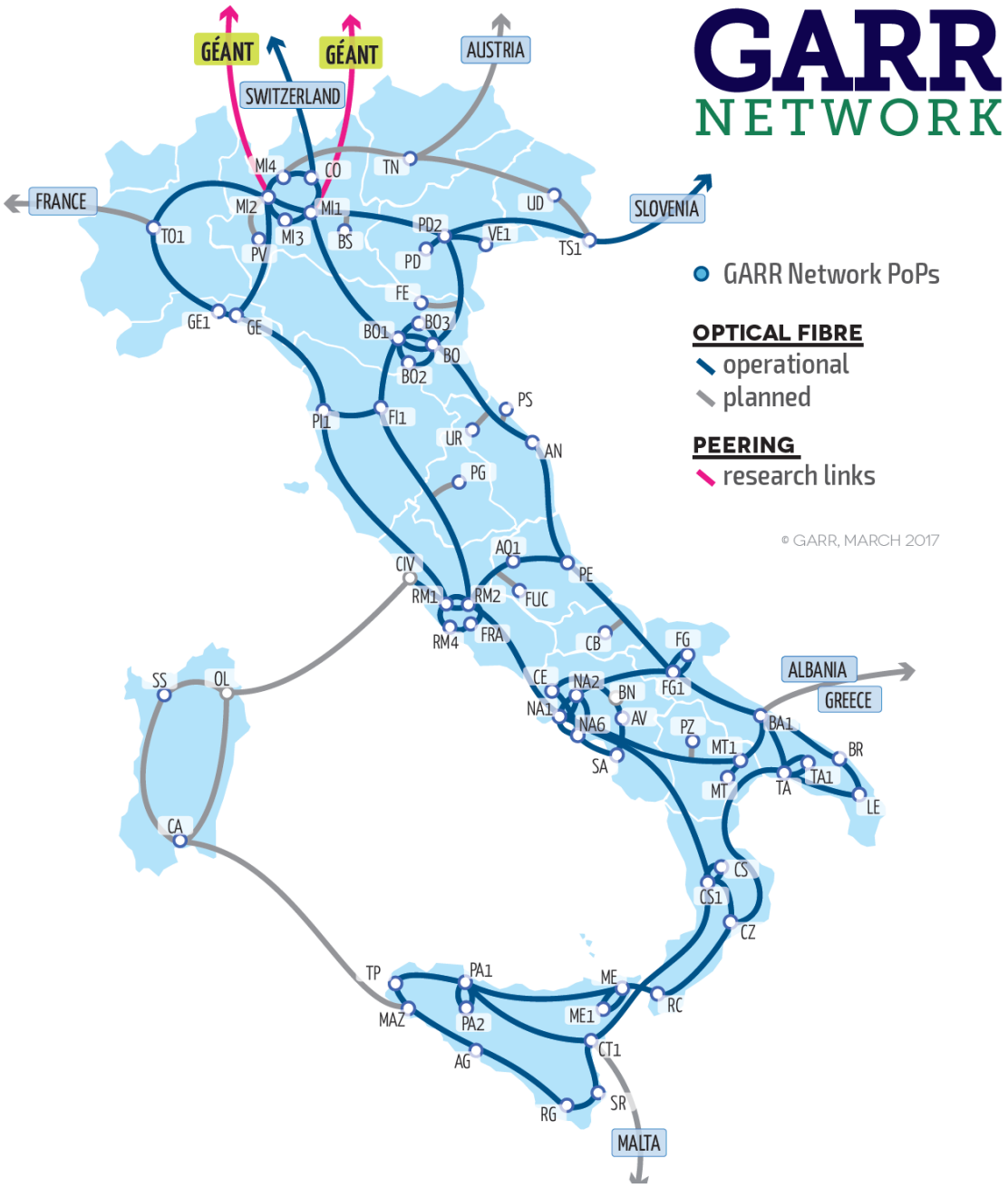


Global IP Backbone




ROTTERDAM

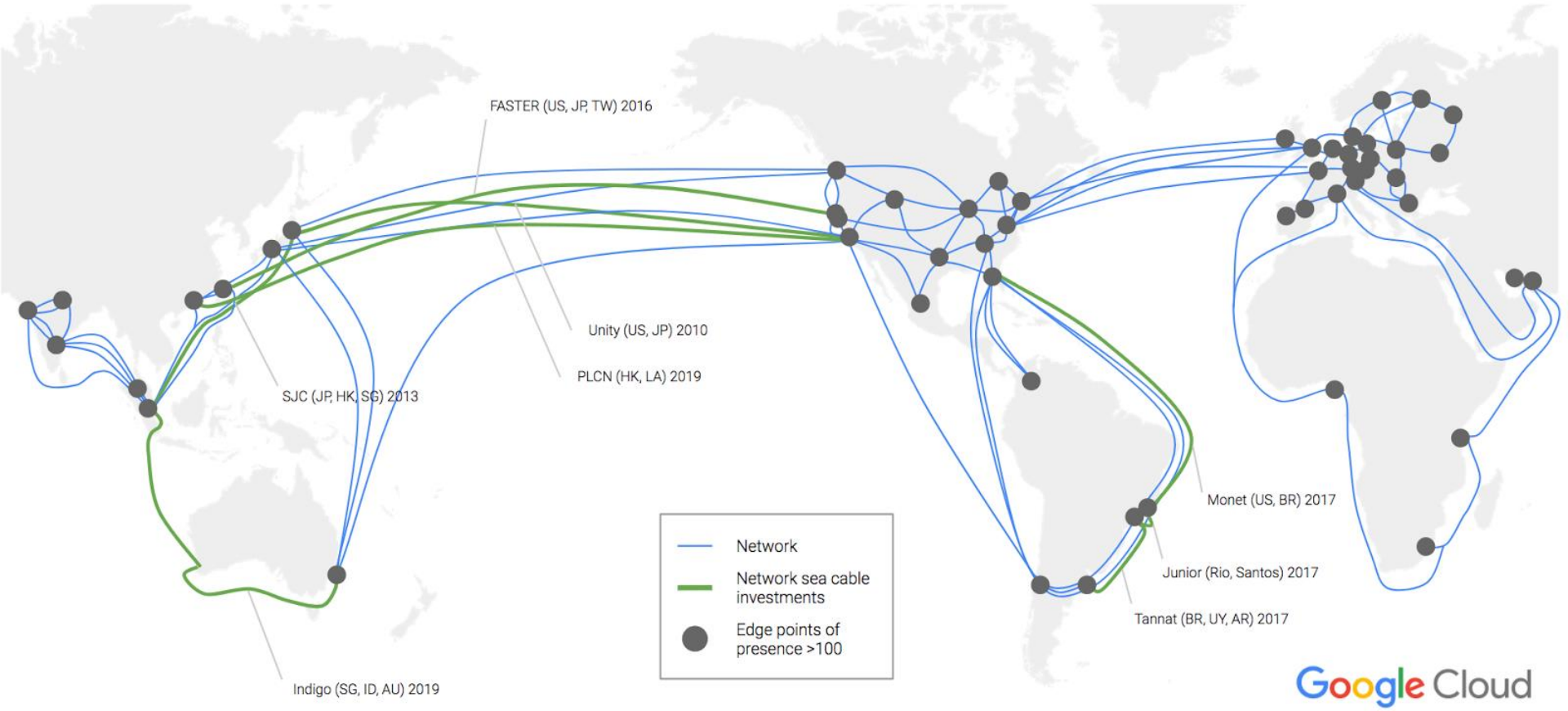



GÉANT
GÉANT
AUSTRIA
SWITZERLAND
FRANCE
SLOVENIA
MI4
CO
TN
MI2
MI1
UD
TO1
MI3
BS
PD2
VE1
PV
PD
TS1
FE
GE1
GE
BO3
BO1
BO
BO2
PS
PI1
FI1
UR
AN
PG
AQ1
CIV
PE
RM1
RM2
FUC
RM4
FRA
CB
FG
ALBANIA
SS
OL
CE
NA2
BN
FG1
GREECE
NA1
AV
NA6
PZ
BA1
MT1
BR
SA
TA
TA1
MT
LE
CA
CS
CS1
CZ
TP
PA1
ME
MAZ
PA2
ME1
RC
AG
CT1
SR
RG
MALTA
GARR
NETWORK
GARR Network PoPs
OPTICAL FIBRE
operational
planned
PEERING
research links
© GARR, MARCH 2017

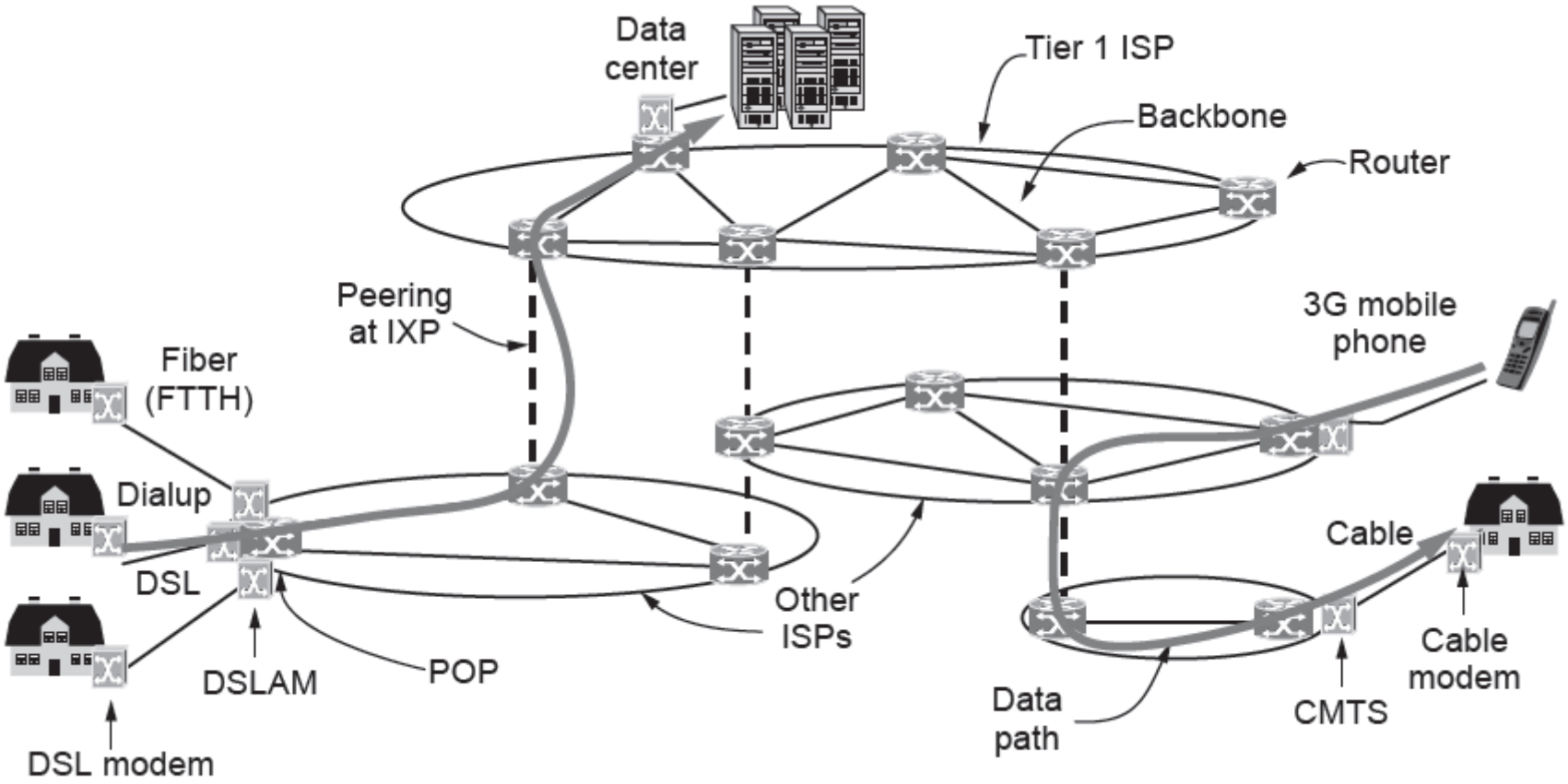
The company has essentially two huge networks: the one that connects users to Google services (Search, Gmail, YouTube, etc.) and another (internal) that connects Google data centers to each other.

Google is in control of scheduling internal traffic (bursty), but it faces difficulties in traffic engineering.

Often Google has to move many petabytes of data (indexes of the entire web, millions of backup copies of user Gmail) from one place to another.

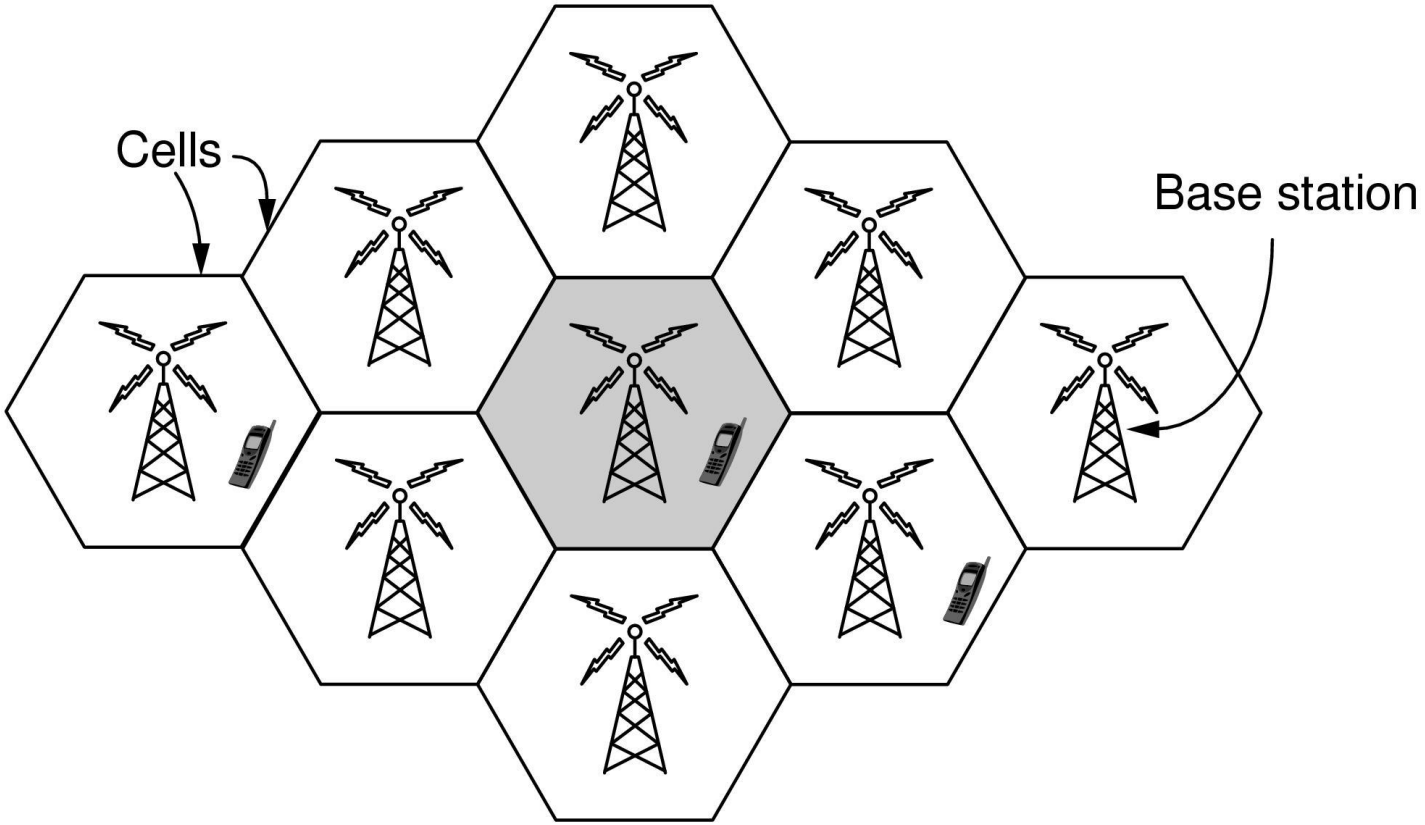

FASTER (US, JP, TW) 2016
Unity (US, JP) 2010
PLCN (HK, LA) 2019
SJC (JP, HK, SG) 2013
Monet (US, BR) 2017
Junior (Rio, Santos) 2017
Tannat (BR, UY, AR) 2017
Indigo (SG, ID, AU) 2019
Network
Network sea cable investments
Edge points of presence >100
Google Cloud

Architecture of the Internet



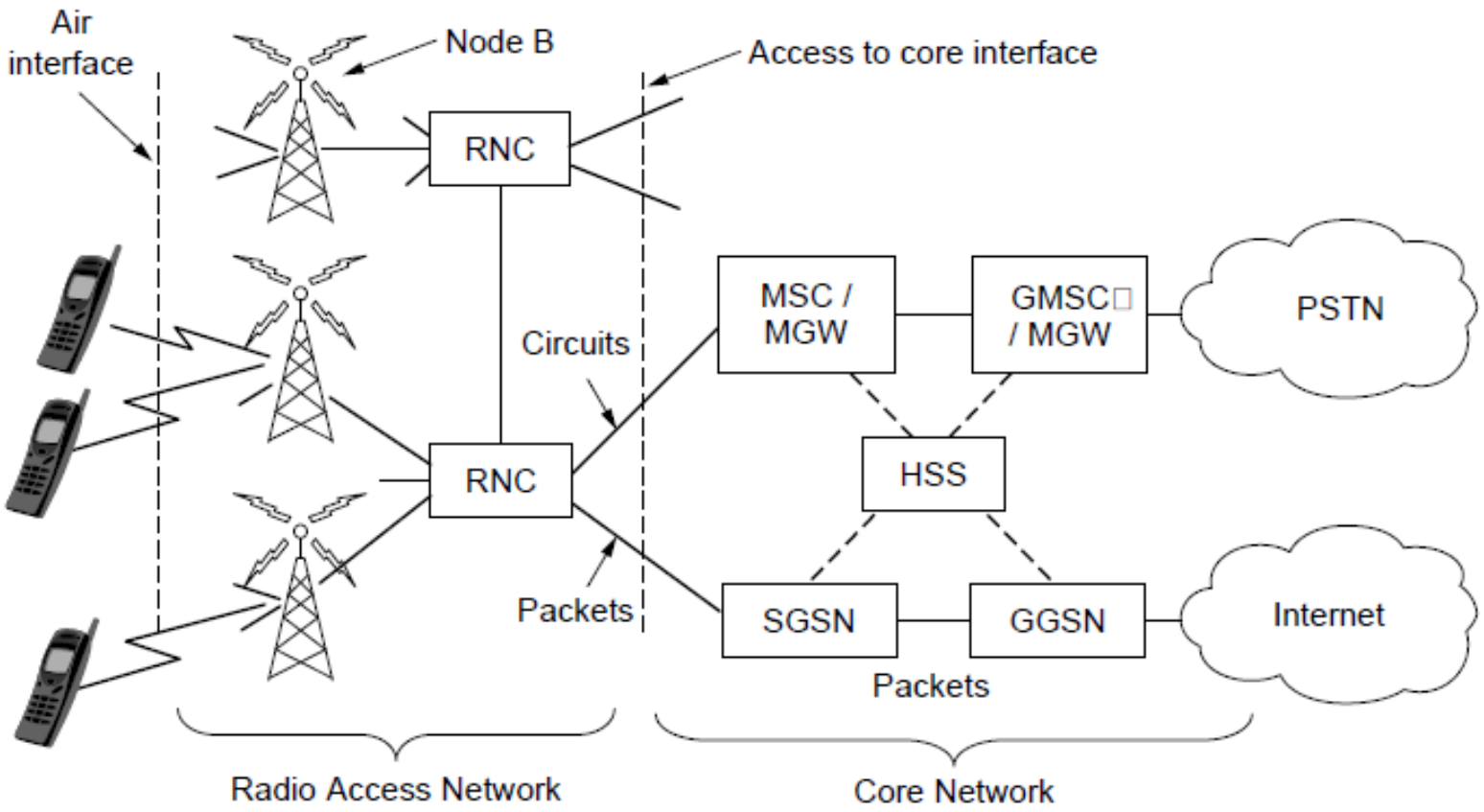
Overview of the Internet architecture

Third-Generation Mobile Phone Networks (1)



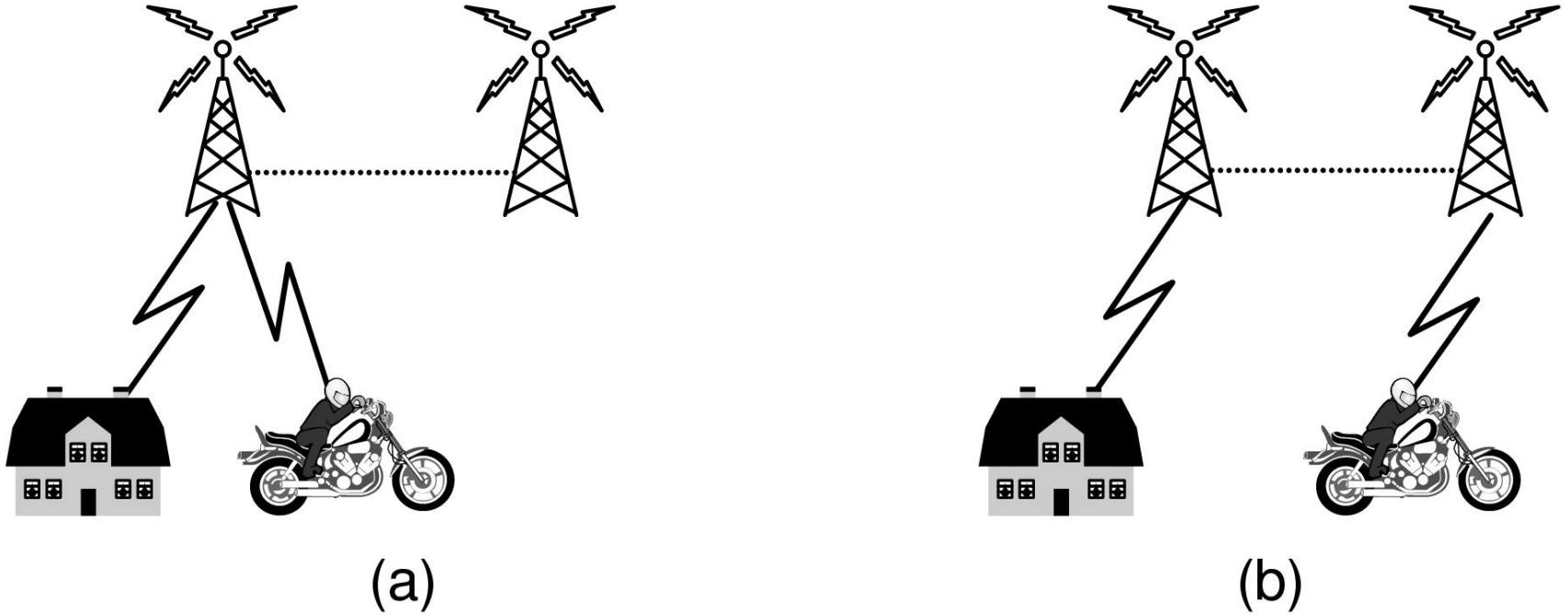
Cellular design of mobile phone networks

Third-Generation Mobile Phone Networks (2)



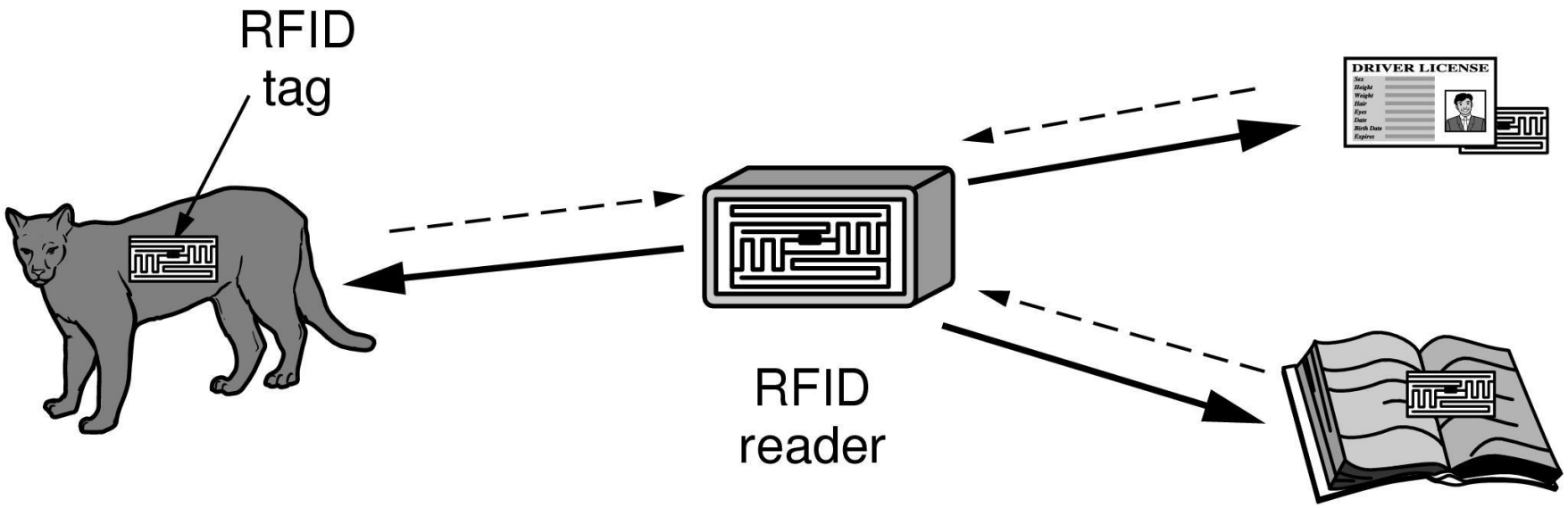
Architecture of the UMTS 3G mobile phone network.

Third-Generation Mobile Phone Networks (3)



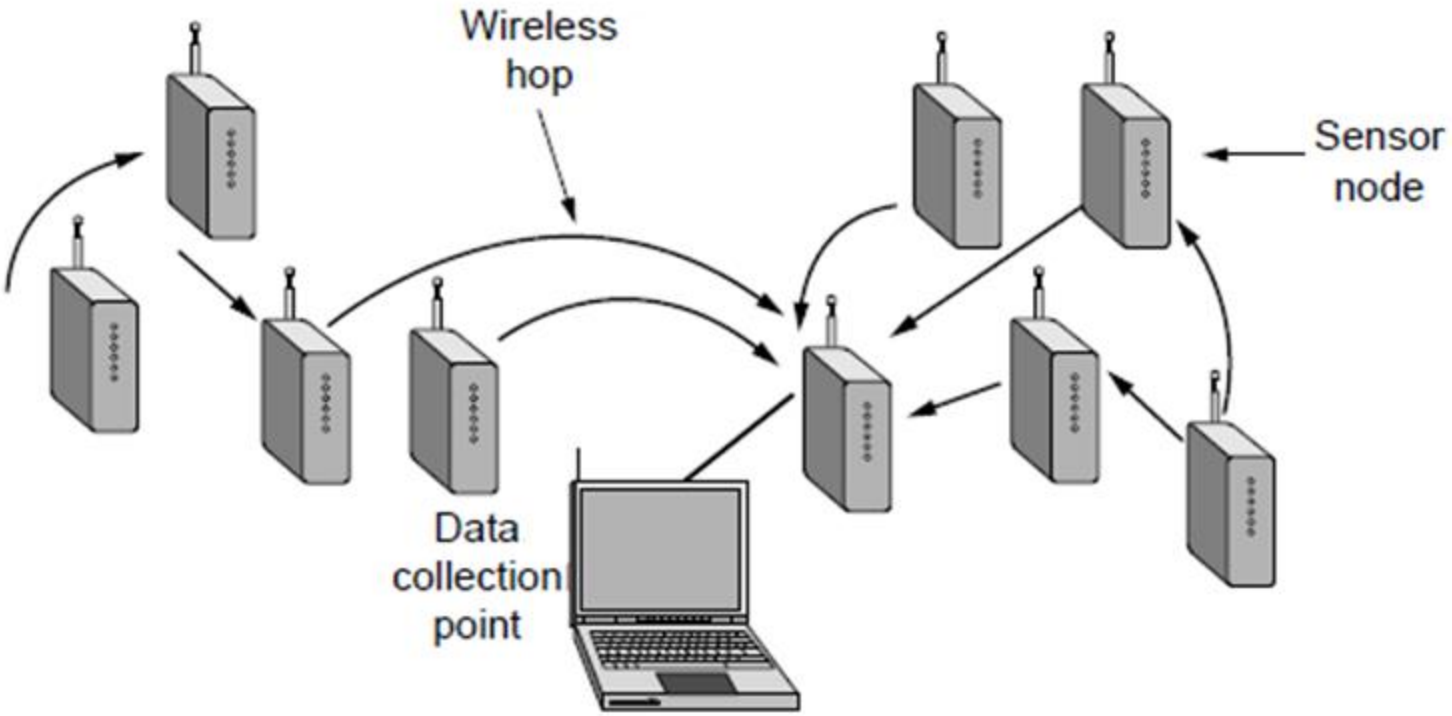
Mobile phone handover (a) before, (b) after.

RFID and Sensor Networks (1)



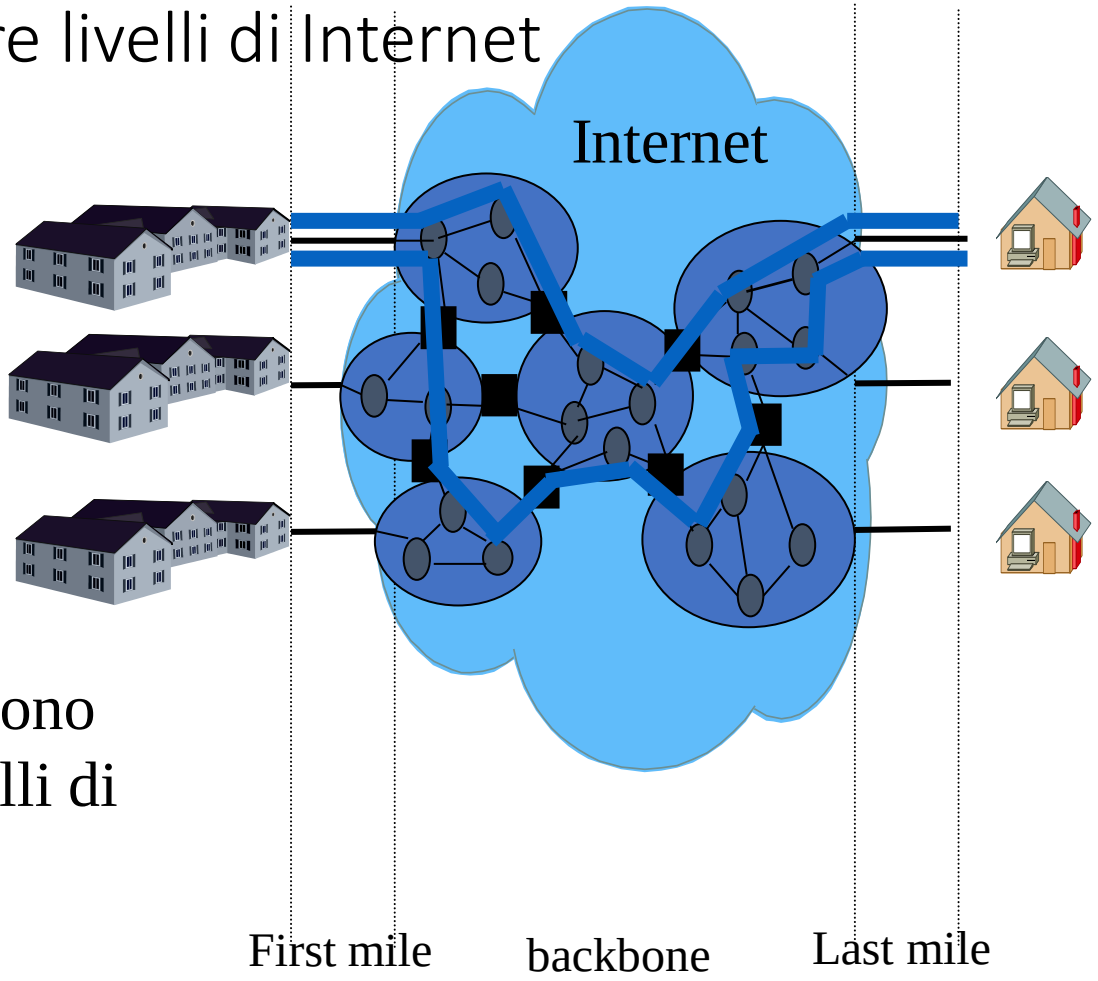
RFID used to network everyday objects.

RFID and Sensor Networks (2)



Multihop topology of a sensor network

Architettura a tre livelli di Internet



Le tre zone sono potenziali colli di bottiglia

■ Neutral/Network access point

ISP o NSP

Architettura a tre livelli di Internet

Eliminare colli di bottiglia (soluzioni hardware)
• first mile, last mile -> aumentare la banda che connette al provider
•Backbone -> dipende dal miglioramento delle infrastrutture di rete dei singoli ISP (non controlabile dagli utenti finali)

Eliminare il collo di bottiglia di backbone (soluzione software)
• Content Delivery Netwoks.
• Caching di pagine vicino a dove risiede l'utente completamente trasparente all'utente (e.g. AKAMAI). In questo modo si spera che l'utente possa accedervi con larga banda

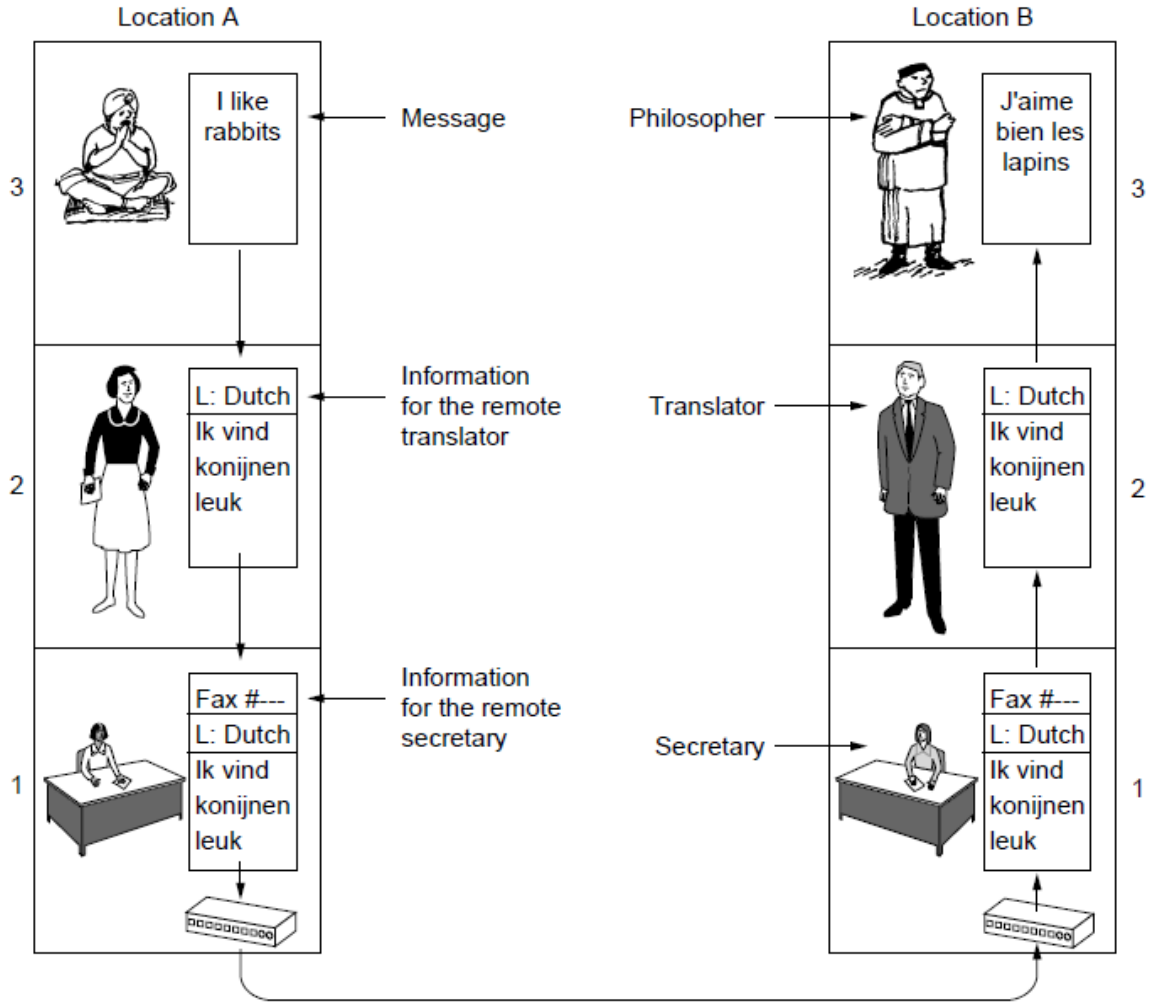
Nota: idea di soluzione simile a quella della gerarchia di caching delle memorie nei processori

Akamai's Global Platform

- **Akamai's Internet Platform**
  - 100,000+ servers
  - 72 countries
  - 1,500+ locations
  - 1,000 networks
- **Ginormous Daily Traffic**
  - Carries 15-30% of the world's web traffic on any given day
  - More than 1 trillion requests
  - More than 30 petabytes
  - 10 million+ concurrent video streams

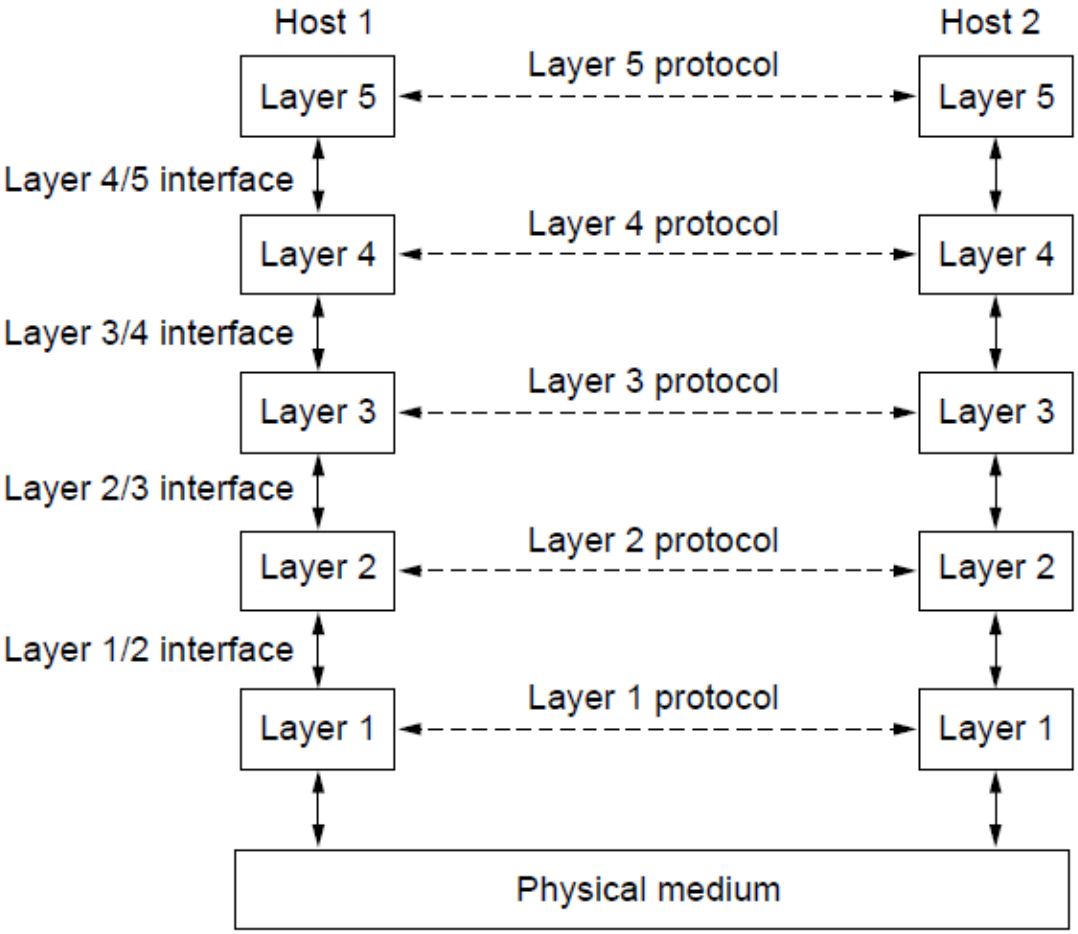
riverbed

Protocol Hierarchies (1)



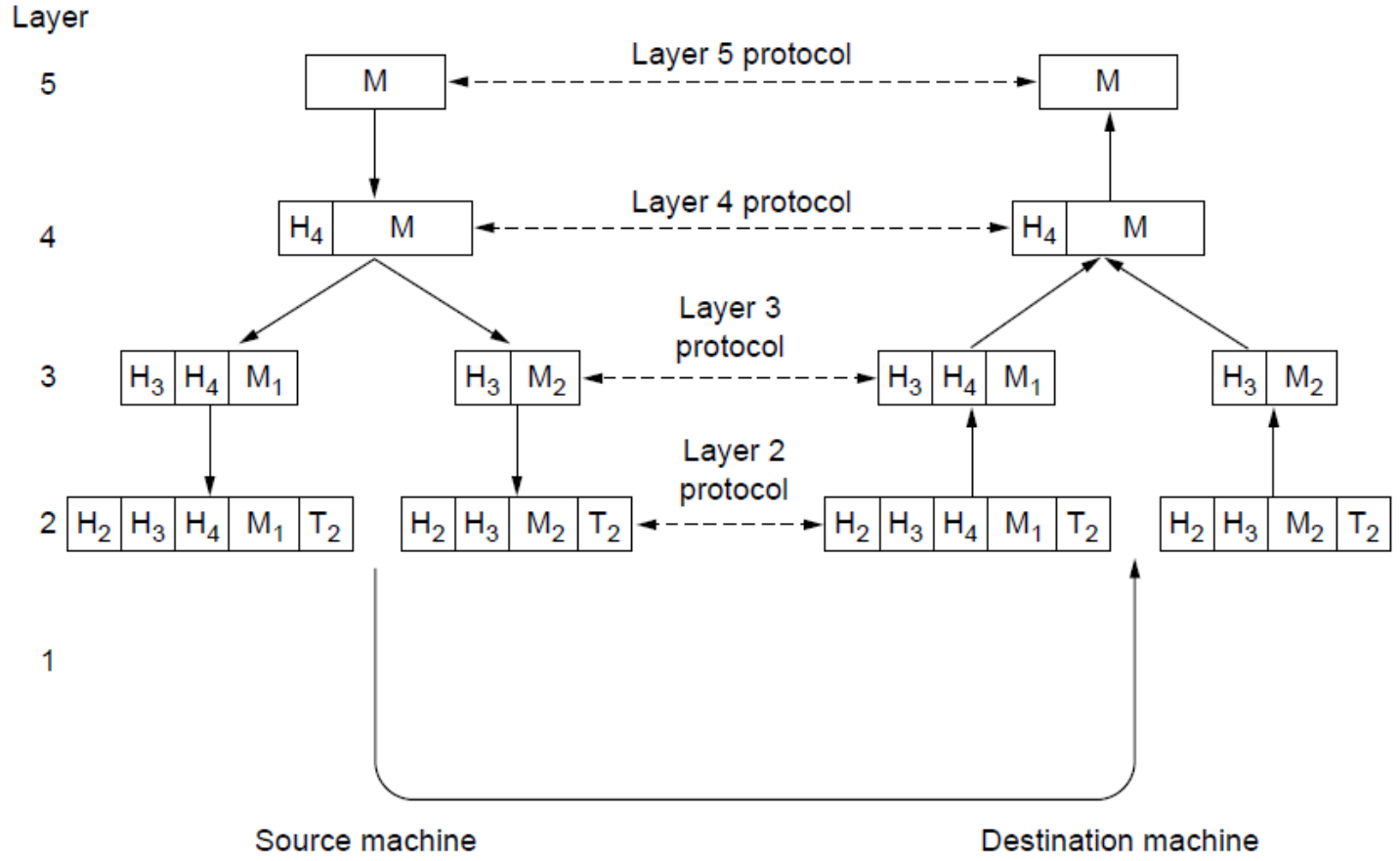
The philosopher-translator-secretary architecture

Protocol Hierarchies (2)



Layers, protocols, and interfaces.

Protocol Hierarchies (3)



Example information flow supporting virtual communication in layer 5.

The OSI Reference Model

Principles for the seven layers

- Layers created for different abstractions
- Each layer performs well-defined function
- Function of layer chosen with definition of international standard protocols in mind
- Minimize information flow across interfaces between boundaries
- Number of layers optimum

Il modello di comunicazione OSI

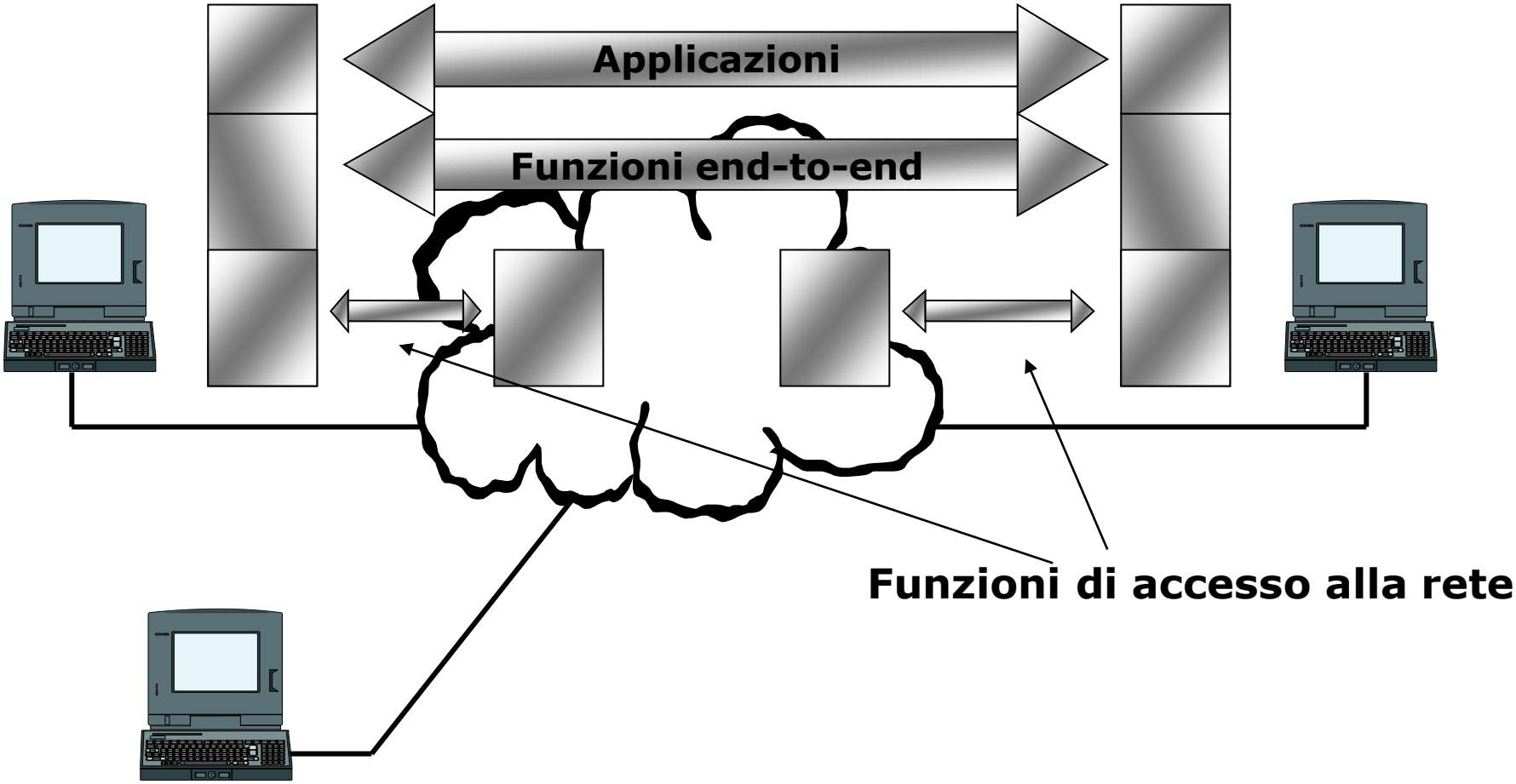
ESEMPIO DI PROFILO DEI PROTOCOLLI PER IL PIANO UTENTE (commutazione di pacchetto)

ESEMPIO DI PROFILO DEI PROTOCOLLI PER IL PIANO UTENTE (commutazione di circuito)

Critique of the OSI Model and Protocols

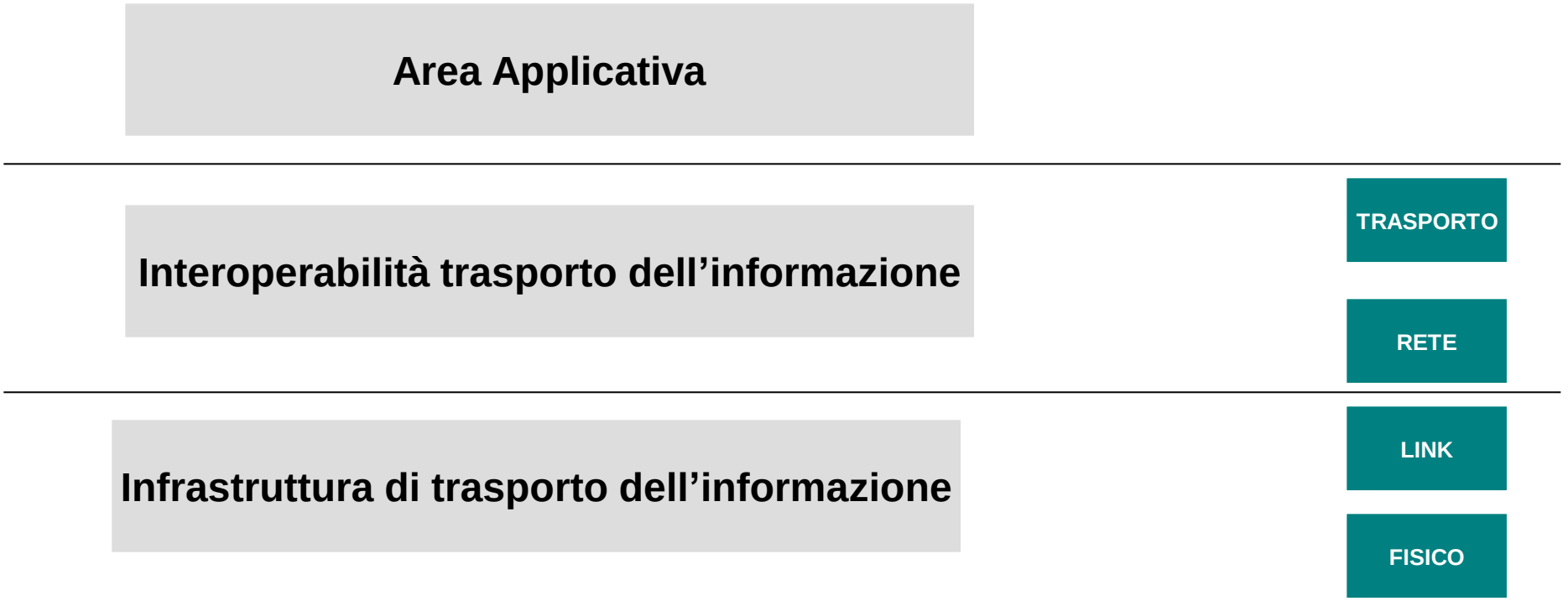
- Bad timing.
- Bad technology.
- Bad implementations.
- Bad politics.

Rete geografica di calcolatori

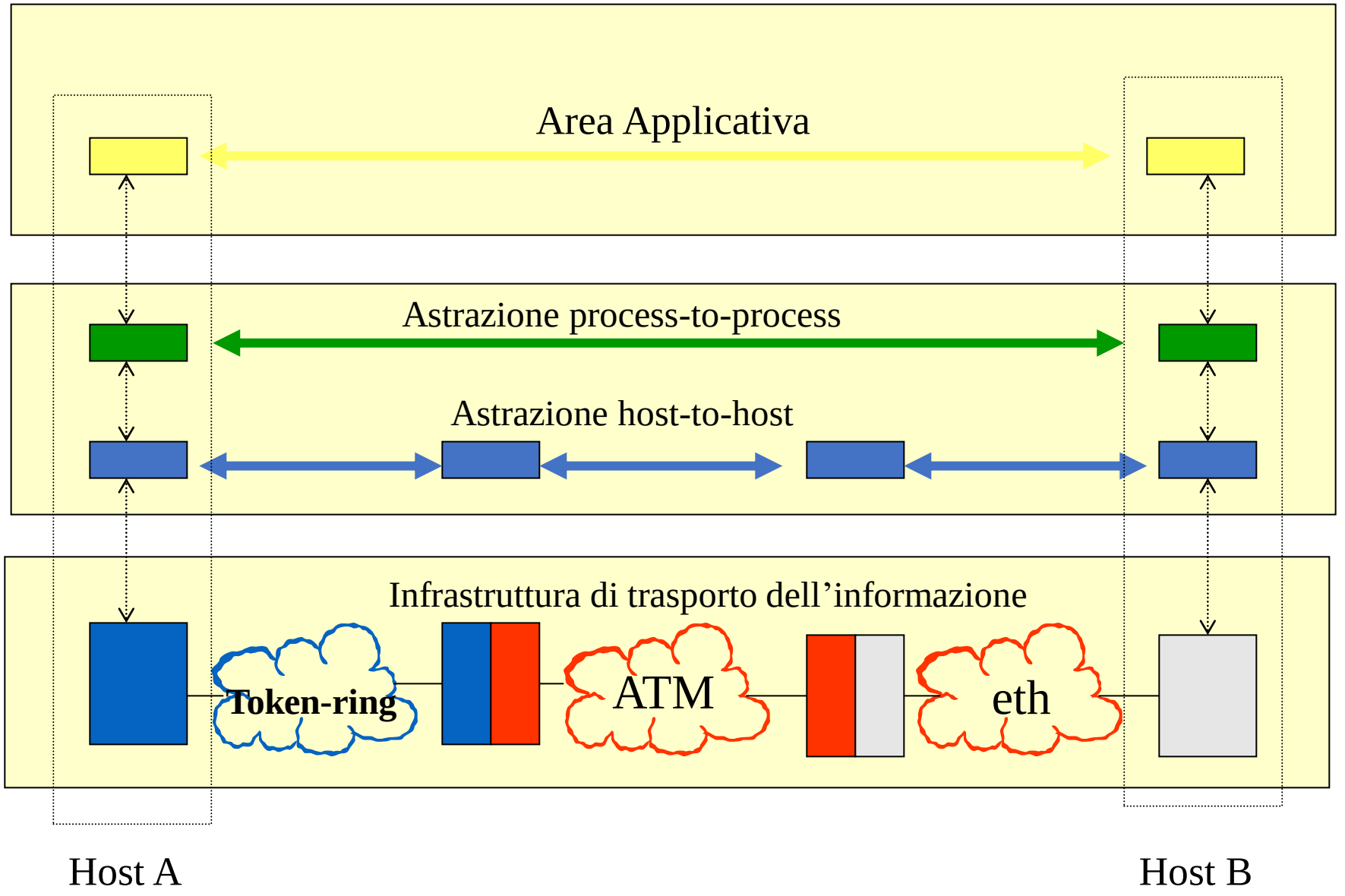


Struttura a tre livelli di una rete di calcolatori

Struttura a tre livelli di una rete di calcolatori

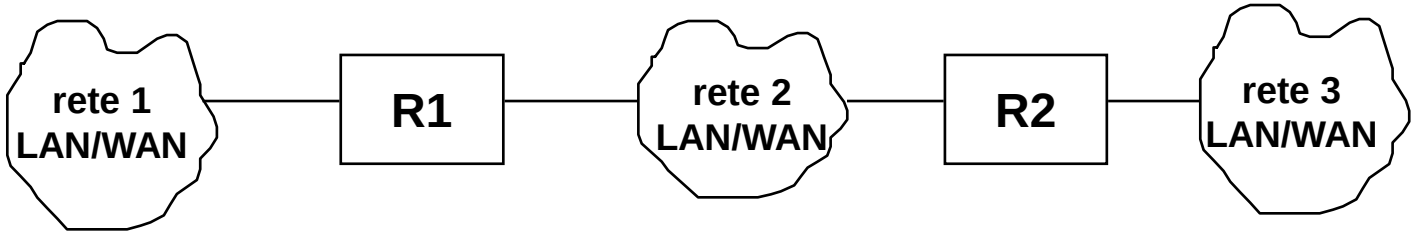


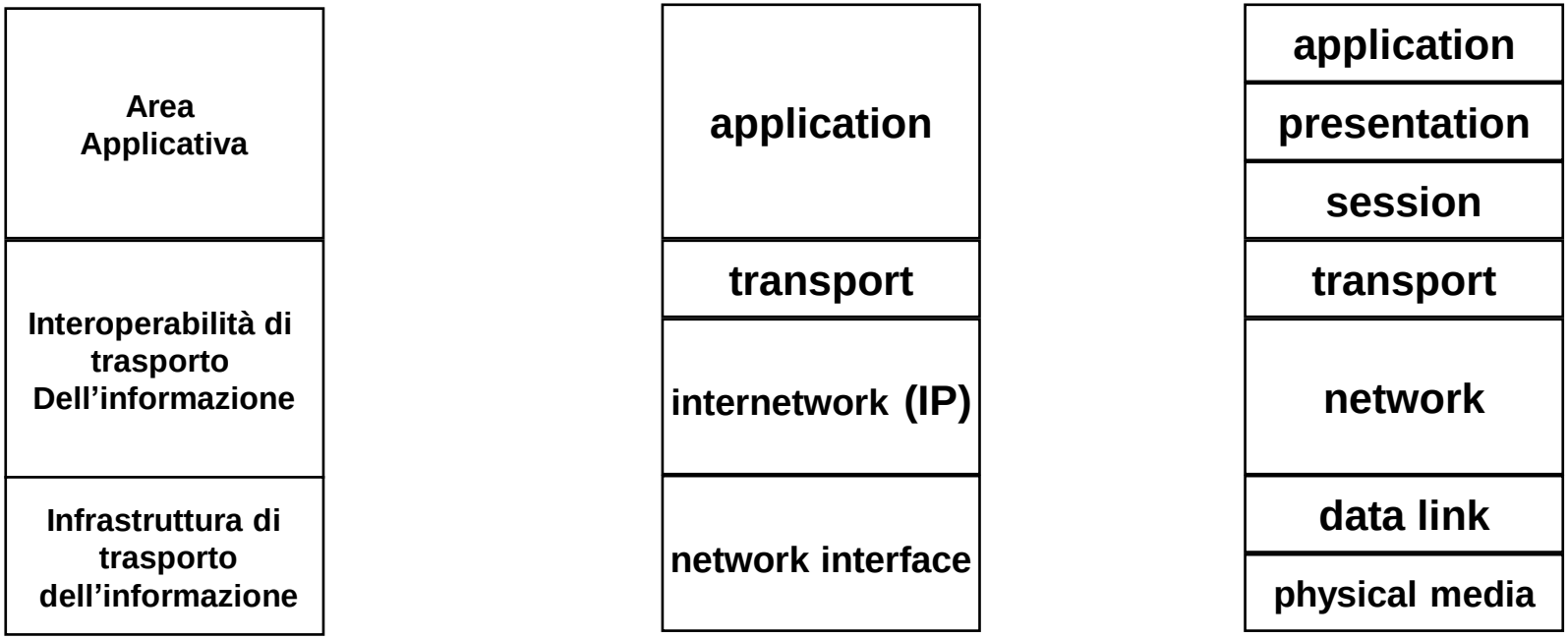
Rete geografica di calcolatori



Esempi di problematiche comuni: Indirizzamento

Interoperabilità Trasporto dell'informazione: Internet



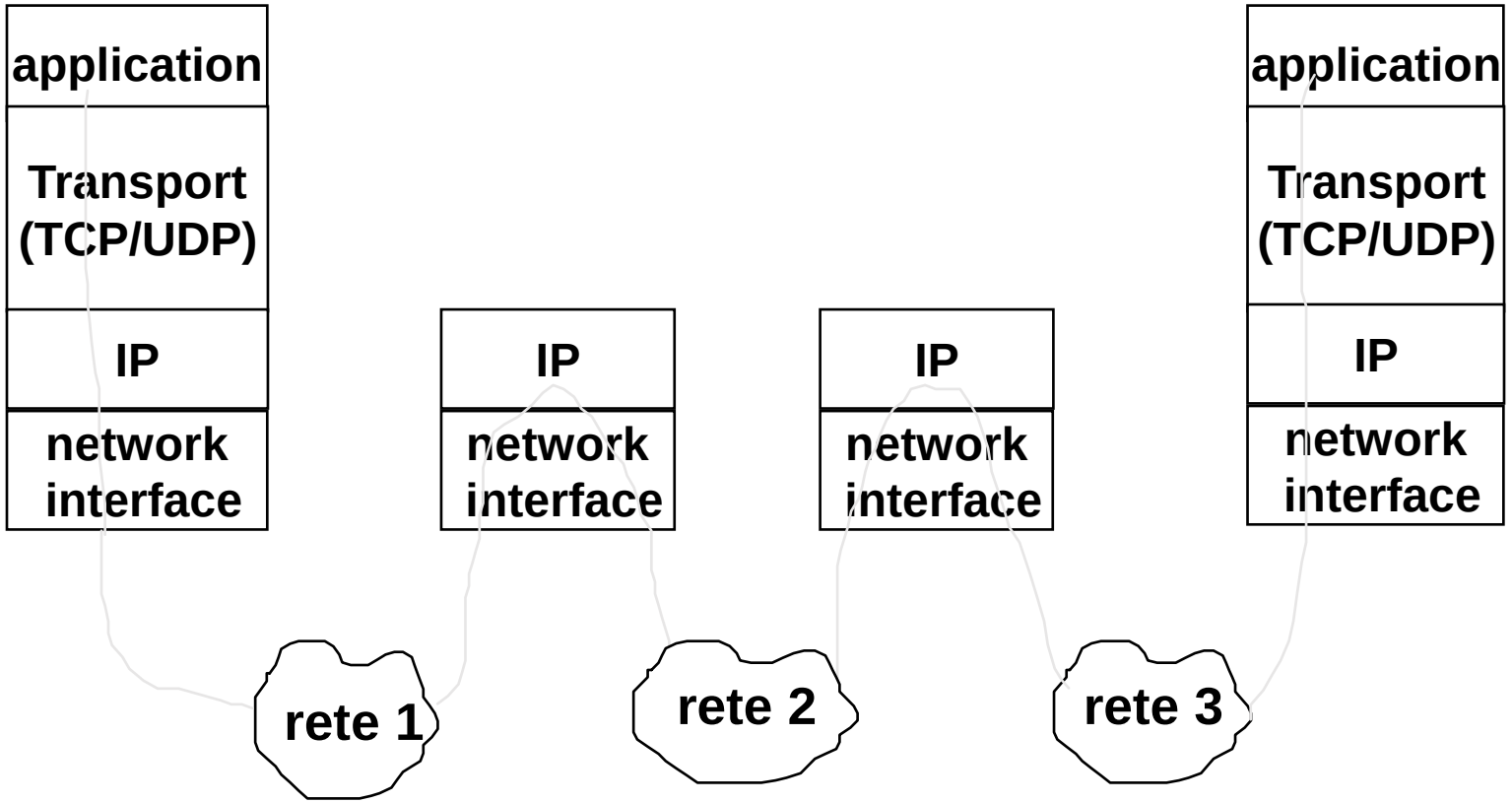


Struttura a tre livelli

Internet

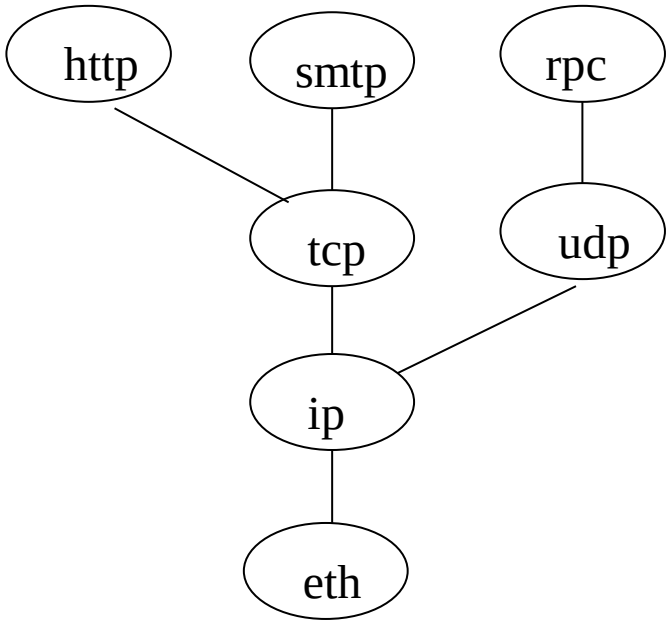
OSI

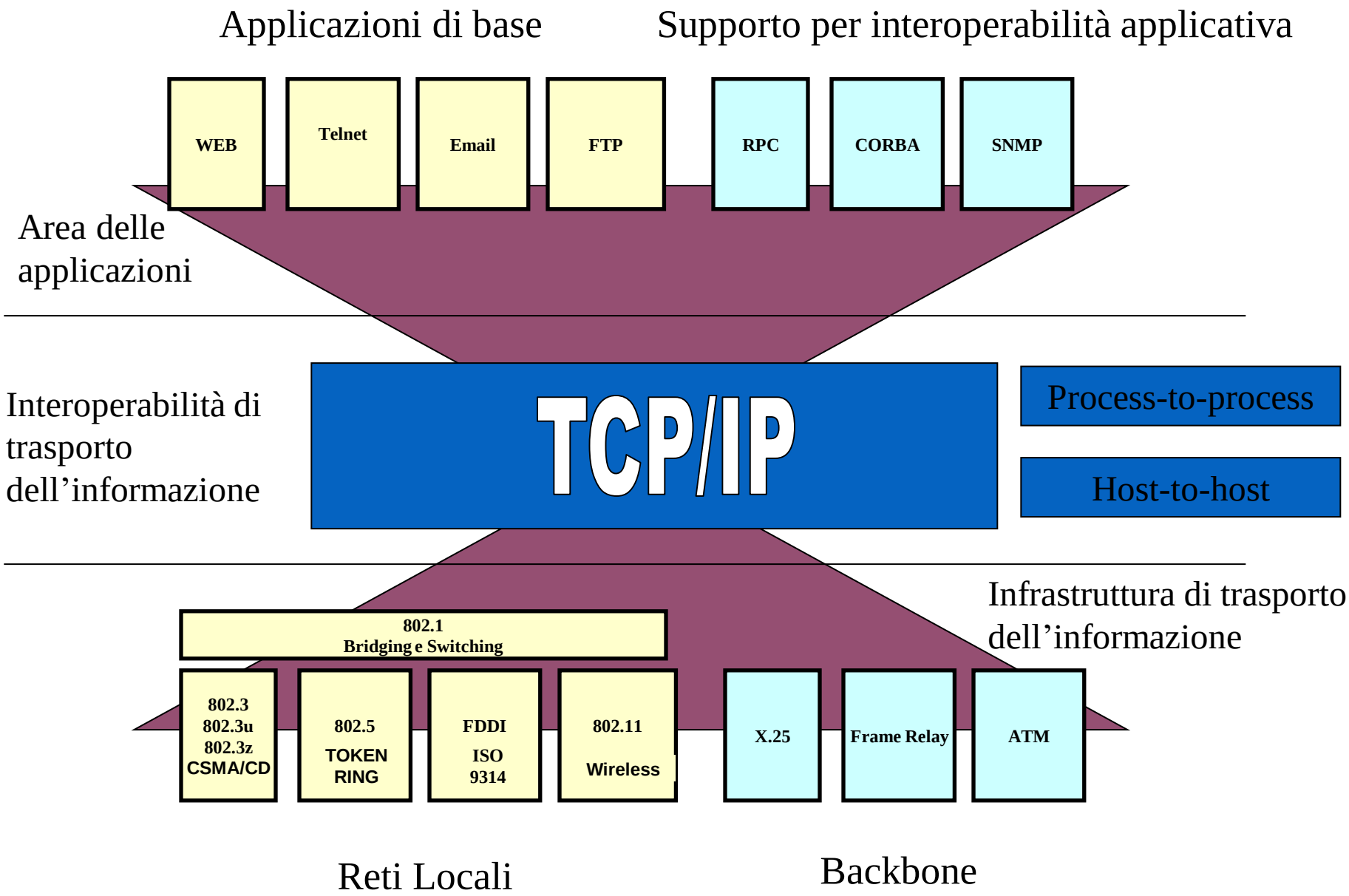
L’ARCHITETTURA TCP/IP E LA RETE INTERNET



Protocol Stack: esempi

http= hyper text tranfer protocol
smtp= simple mail transfer protocol
Rpc= remote procedure call




Applicazioni di base
Supporto per interoperabilità applicativa
WEB
Telnet
Email
FTP
RPC
CORBA
SNMP
Area delle applicazioni
Interoperabilità di trasporto dell'informazione
TCP/IP
Process-to-process
Host-to-host
Infrastruttura di trasporto dell'informazione
802.1
Bridging e Switching
802.3
802.3u
802.3z
CSMA/CD
802.5
TOKEN RING
FDDI
ISO 9314
802.11
Wireless
X.25
Frame Relay
ATM
Reti Locali
Backbone

Basi di TCP/IP

Il protocollo IP

- IP e' una grande coperta che nasconde ai protocolli sovrastanti tutte le disomogeneità della infrastruttura di trasporto dell'informazione
- Per far questo necessità di due funzionalità di base:
  - Indirizzamento di rete (indirizzi omogenei a dispetto della rete fisica sottostante)
  - Instradamento dei pacchetti (Routing) (capacità di inviare pacchetti da un host ad un altro utilizzando gli indirizzi definiti al punto precedente)

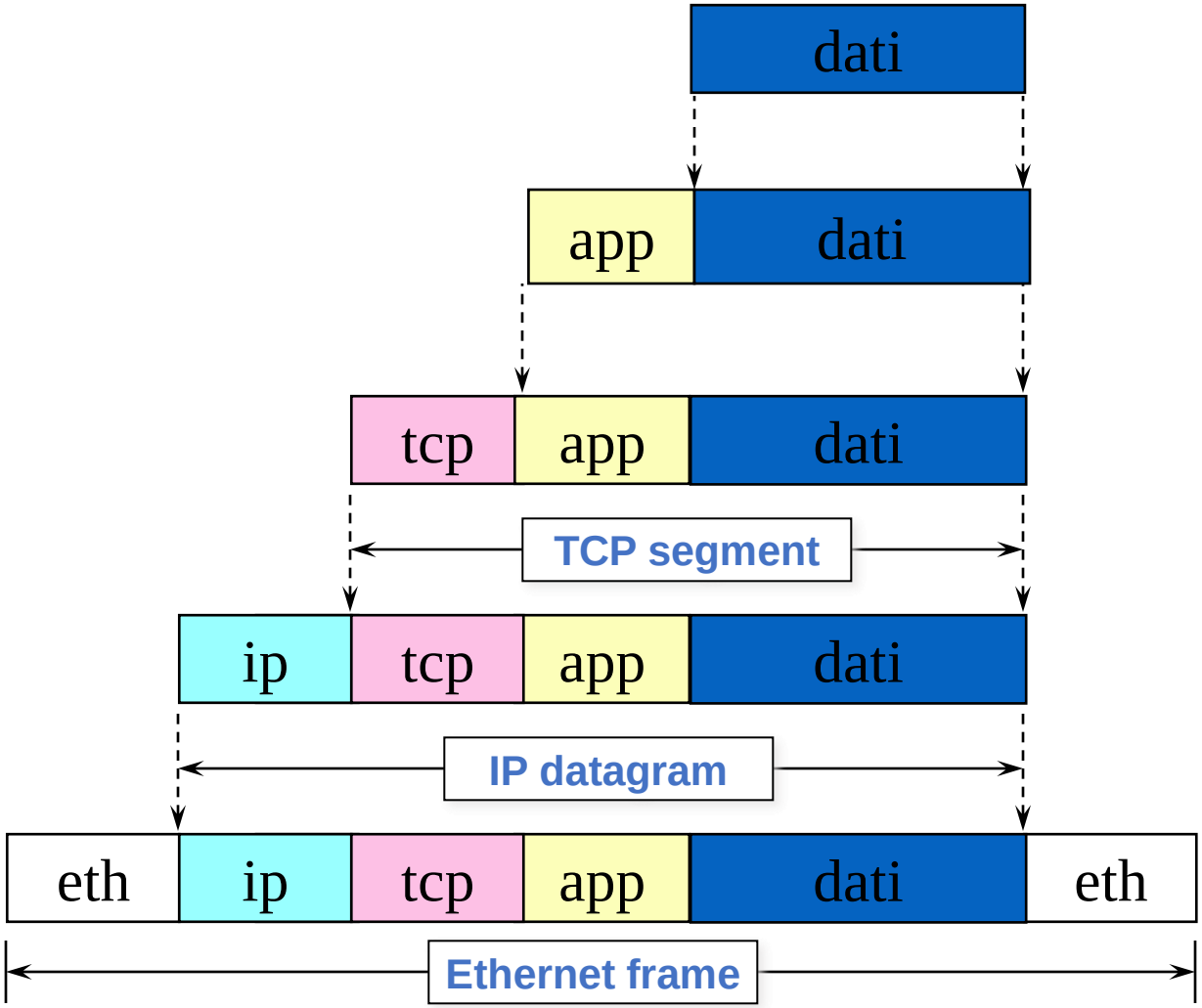
Proprietà di IP

- Senza connessione (datagram based)
- Consegna Best effort
  - I pacchetti possono perdersi
  - I pacchetti possono essere consegnati non in sequenza
  - I pacchetti possono essere duplicati
  - I pacchetti possono subire ritardi arbitrari

Servizi di compatibilità con l'hardware sottostante

- Frammentazione e riassemblaggio
- Corrispondenza con gli indirizzi dei livelli sottostanti (ARP)

Il protocollo IP



Il protocollo IP

In Trasmissione, IP

- **riceve il segmento dati dal livello di trasporto**

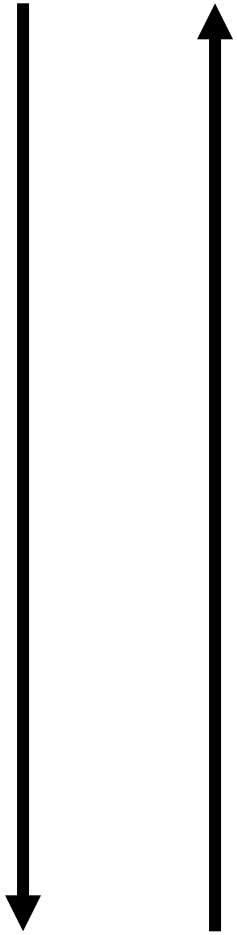
Segmento dati

- **inserisce header e crea datagram**

IP Segmento dati

- **applica l'algoritmo di routing**

- **invia i dati verso l'opportuna interfaccia di rete**



In Ricezione, IP

- **consegna il segmento al protocollo di trasporto individuato**

Segmento dati

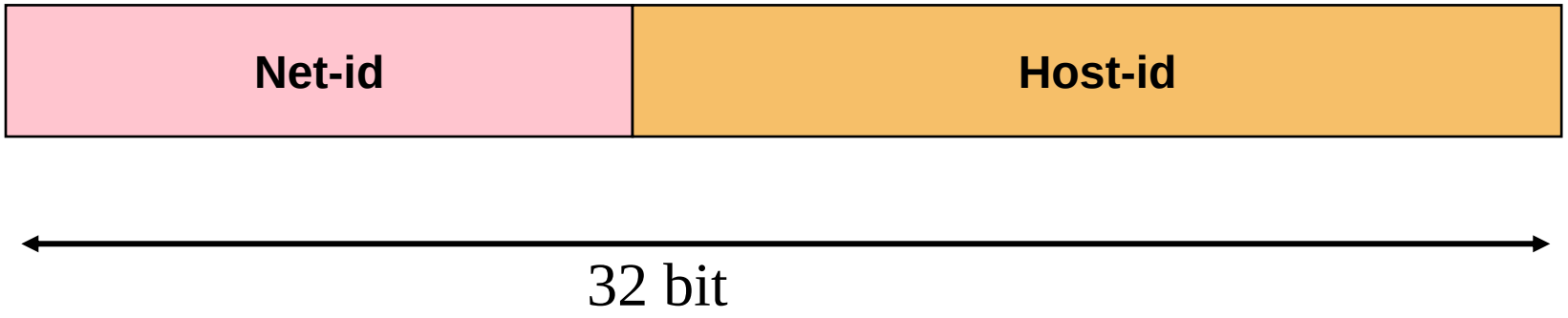
- **se sono dati locali, individua il protocollo di trasporto, elimina l'intestazione**

IP Segmento dati

- **verifica la validità del datagram e l'indirizzo IP**

- **riceve i dati dalla interfaccia di rete**

Indirizzamento

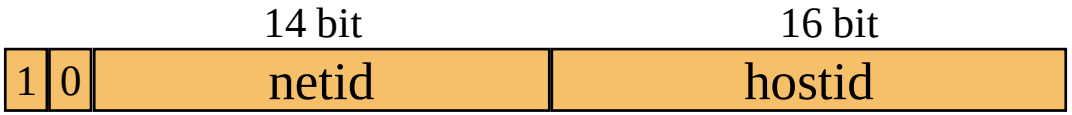


Classi di indirizzi

Classe A **(0.0.0.0 - 127.255.255.255)**

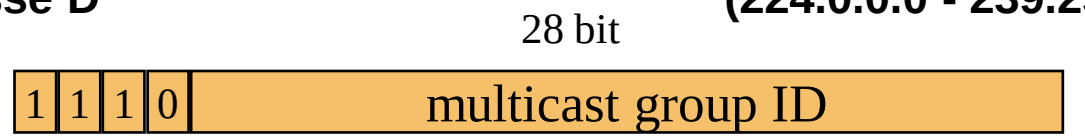
127.0.0.0 riservato

Classe B **(128.0.0.0 - 191.255.255.255)**

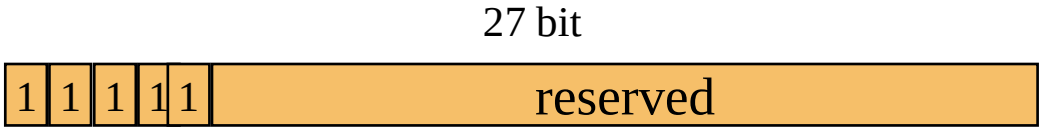


Classe C **(192.0.0.0 - 223.255.255.255)**

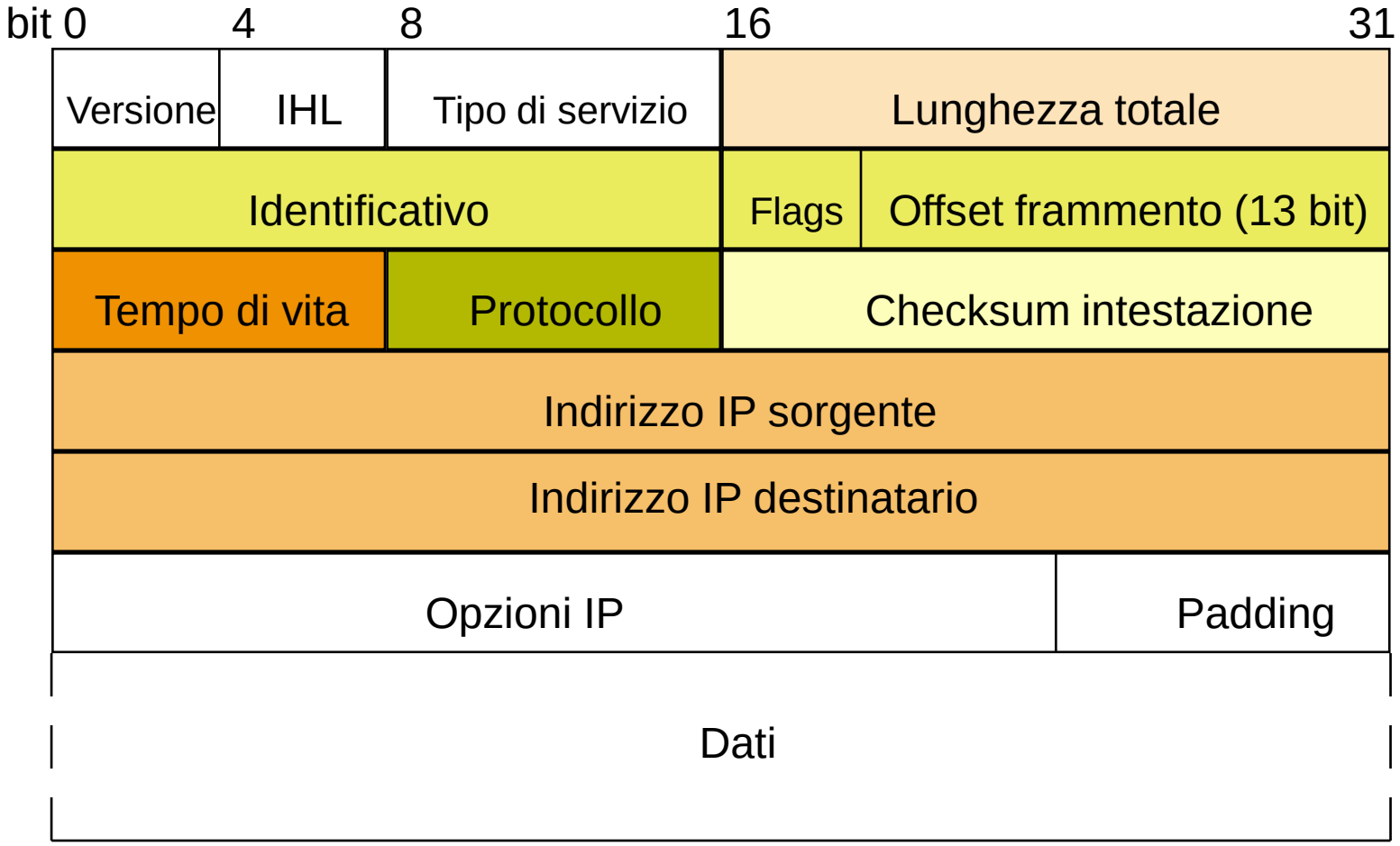
Classe D **(224.0.0.0 - 239.255.255.255)**



Classe E **(240.0.0.0 - 255.255.255.254)**

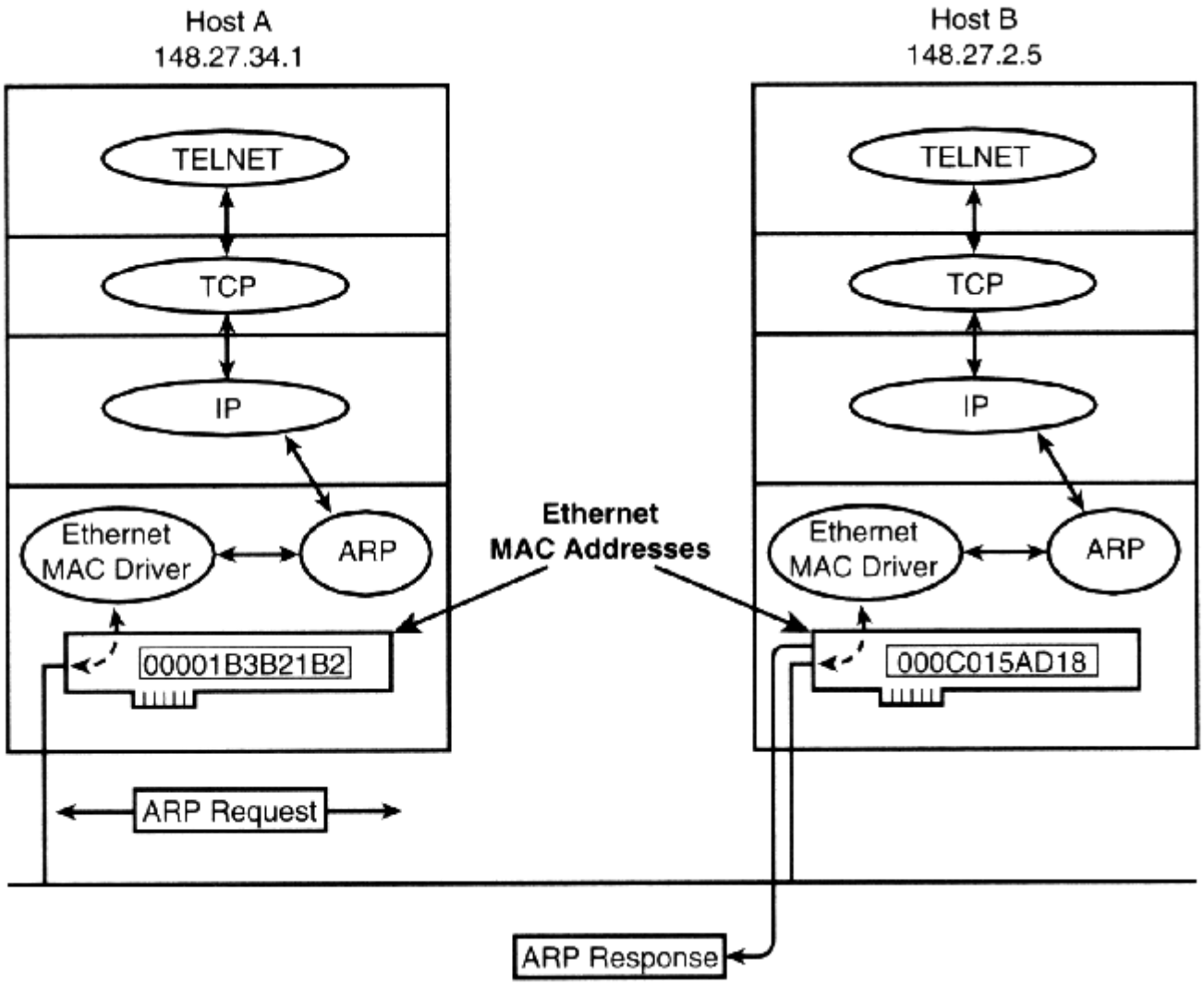


Il protocollo IP

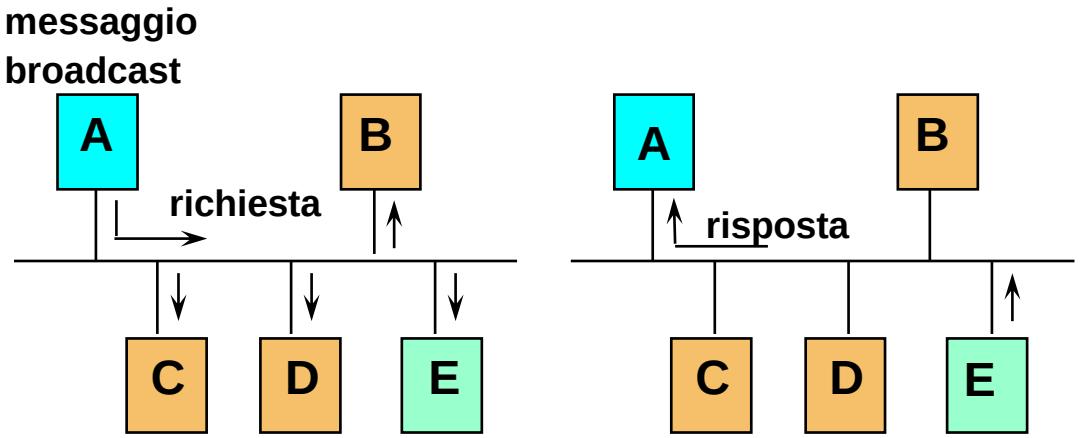


Address Resolution Protocol: ARP

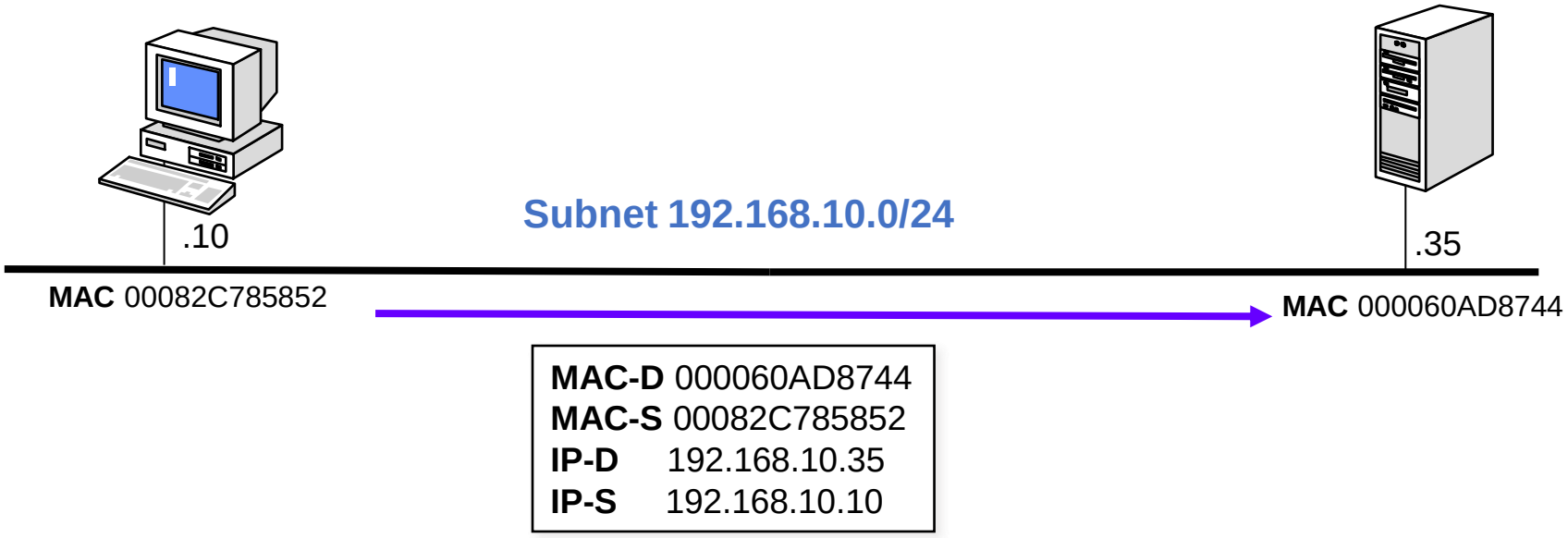
FIGURE 4.9.
Resolution of an IP address into its MAC address using ARP.



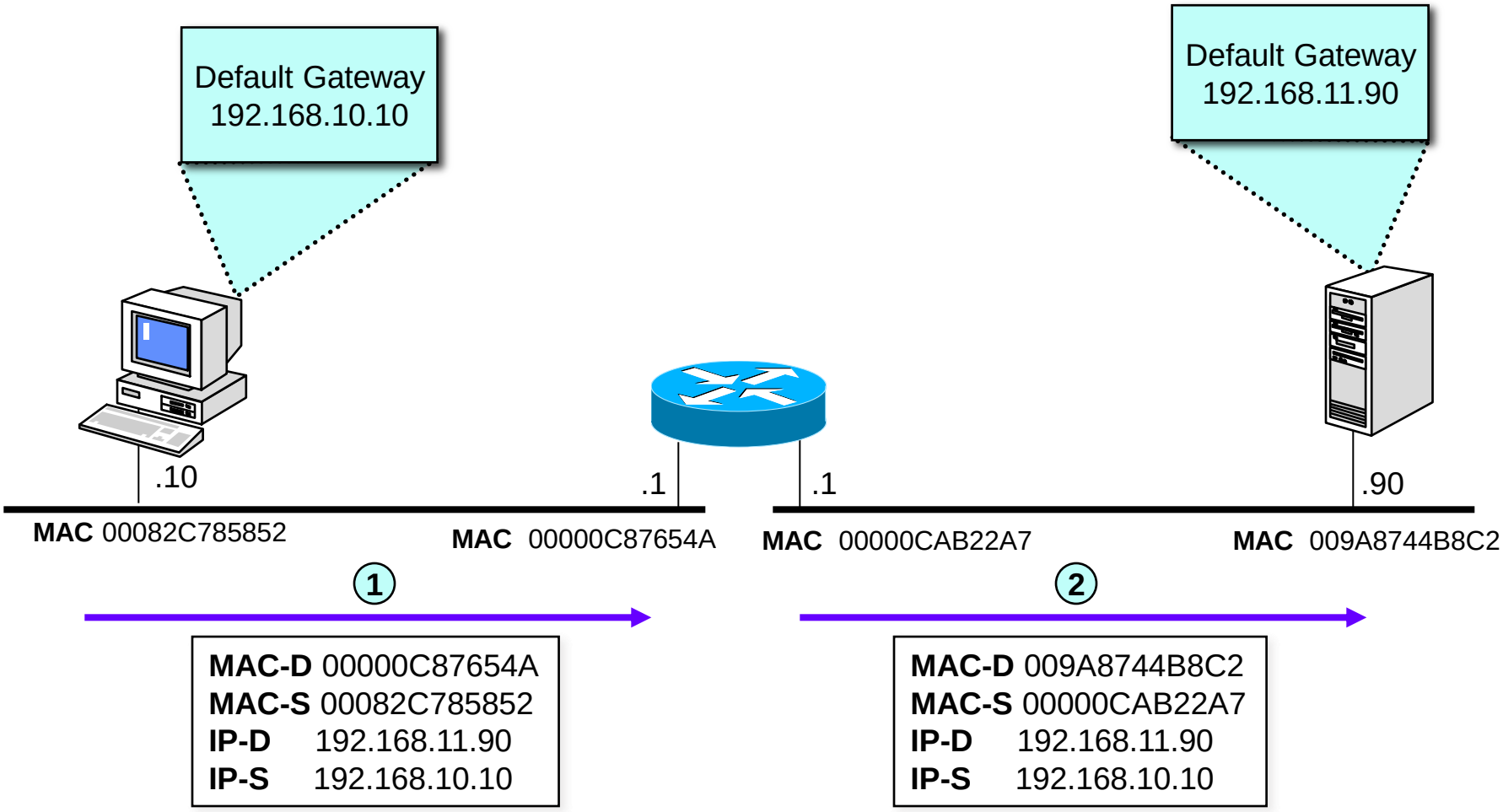
Address Resolution Protocol: ARP



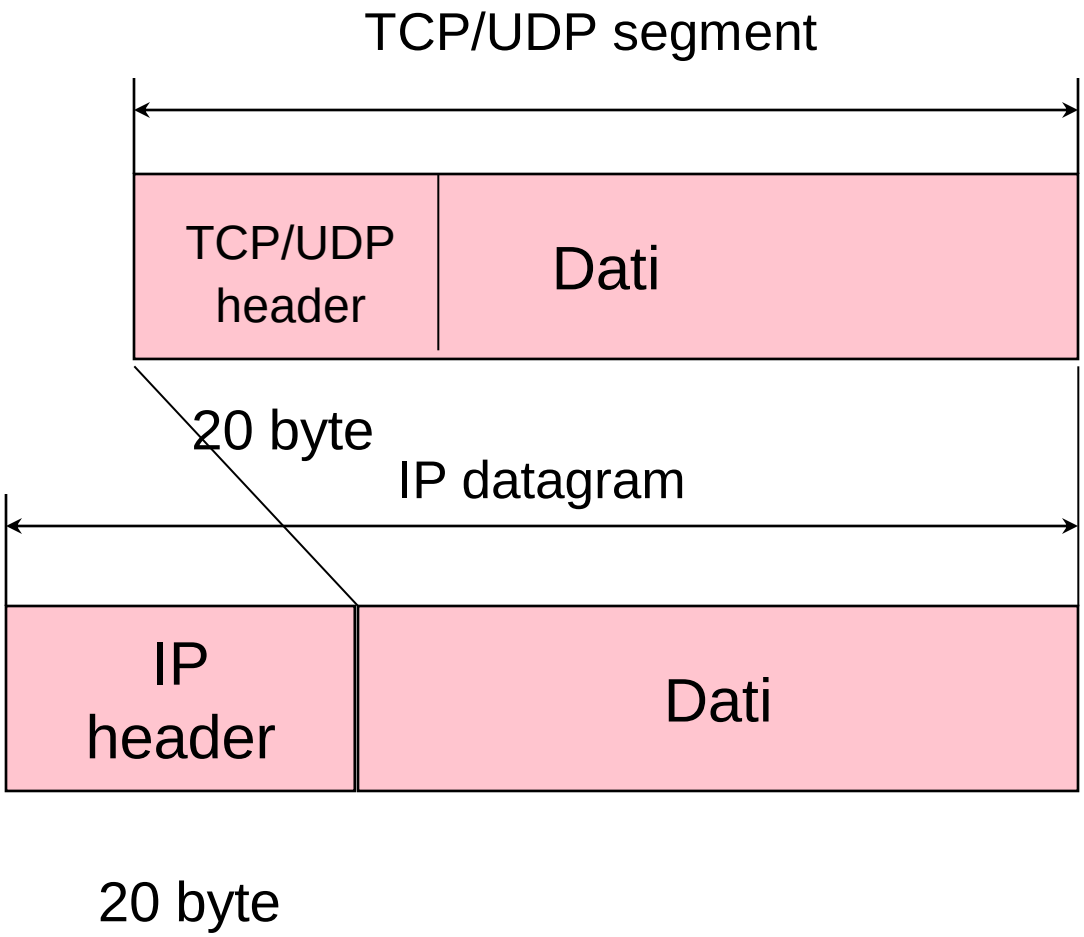
Forwarding diretto: esempio



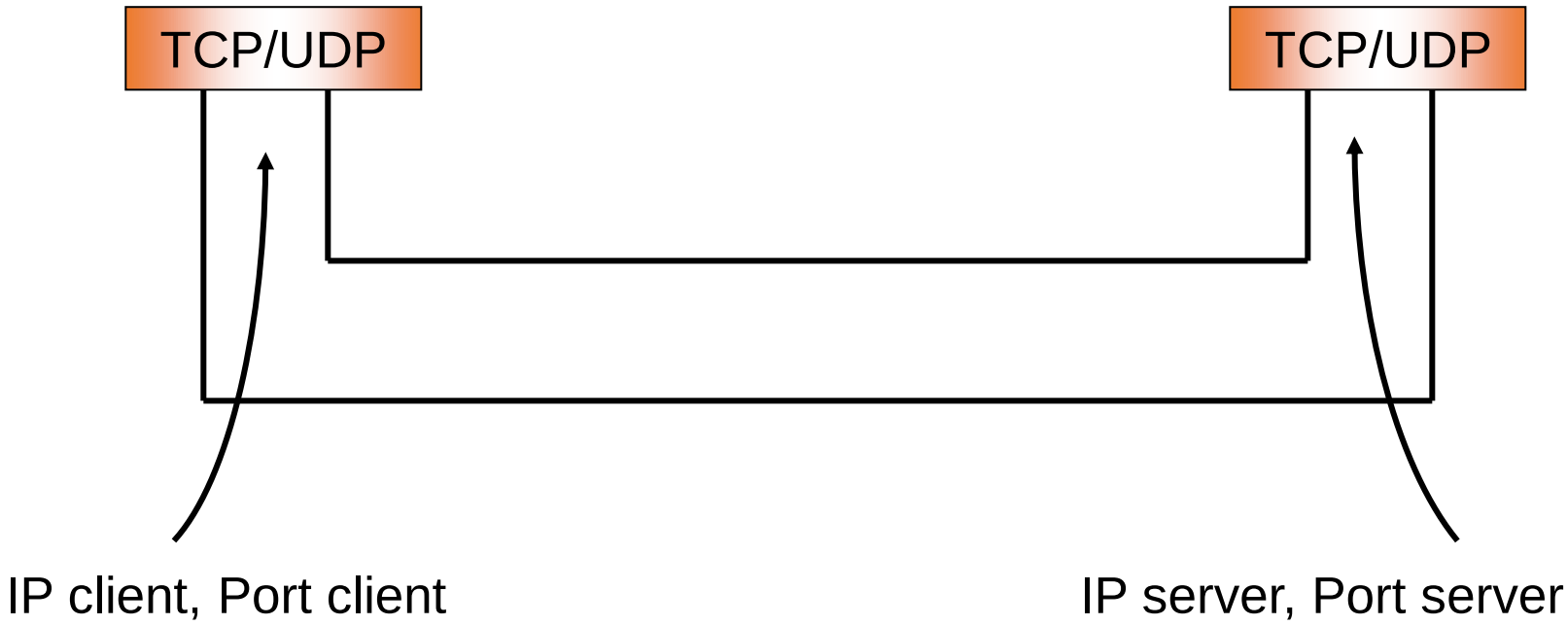
Forwarding indiretto: esempio



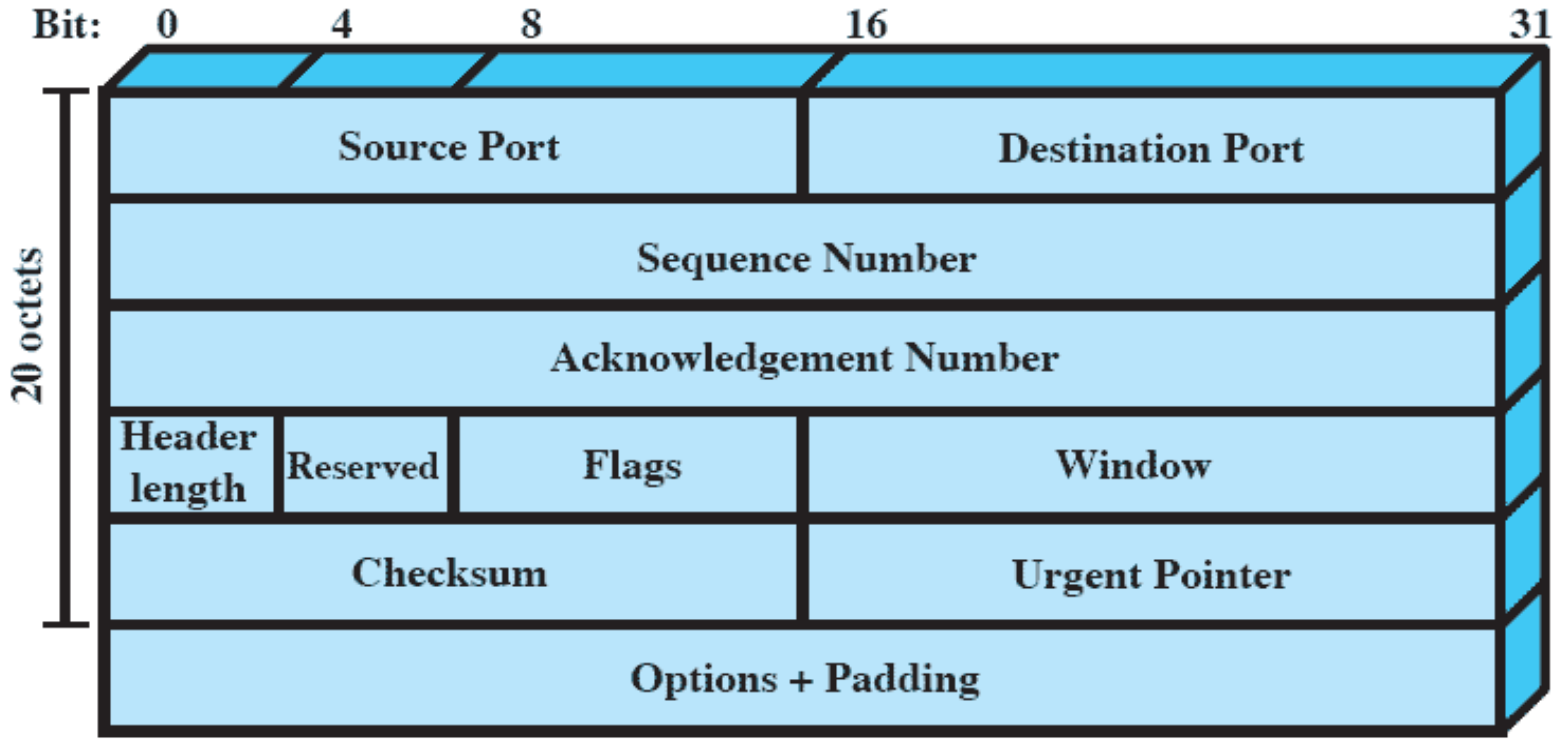
Strato di Trasporto



Strato di Trasporto



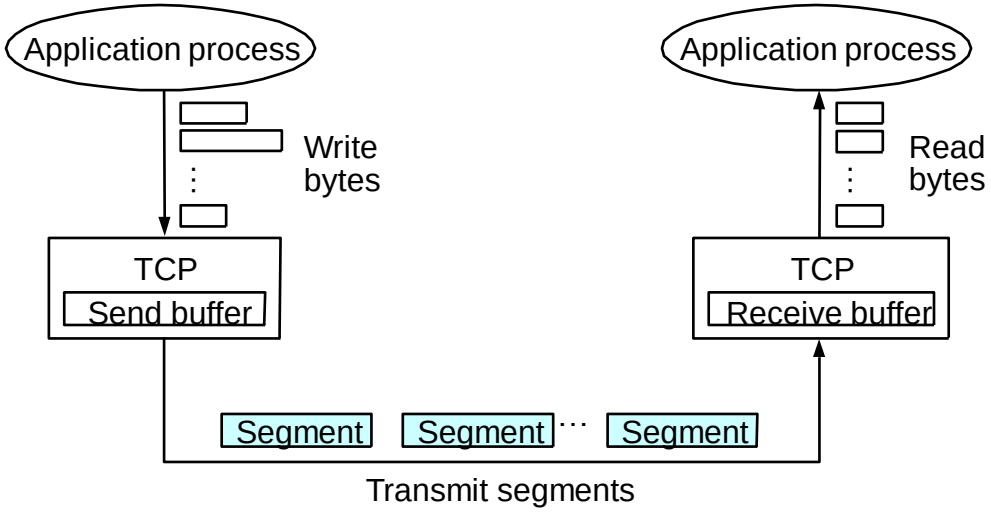
TCP header


Bit:
0
4
8
16
31
20 octets
Source Port
Destination Port
Sequence Number
Acknowledgement Number
Header length
Reserved
Flags
Window
Checksum
Urgent Pointer
Options + Padding

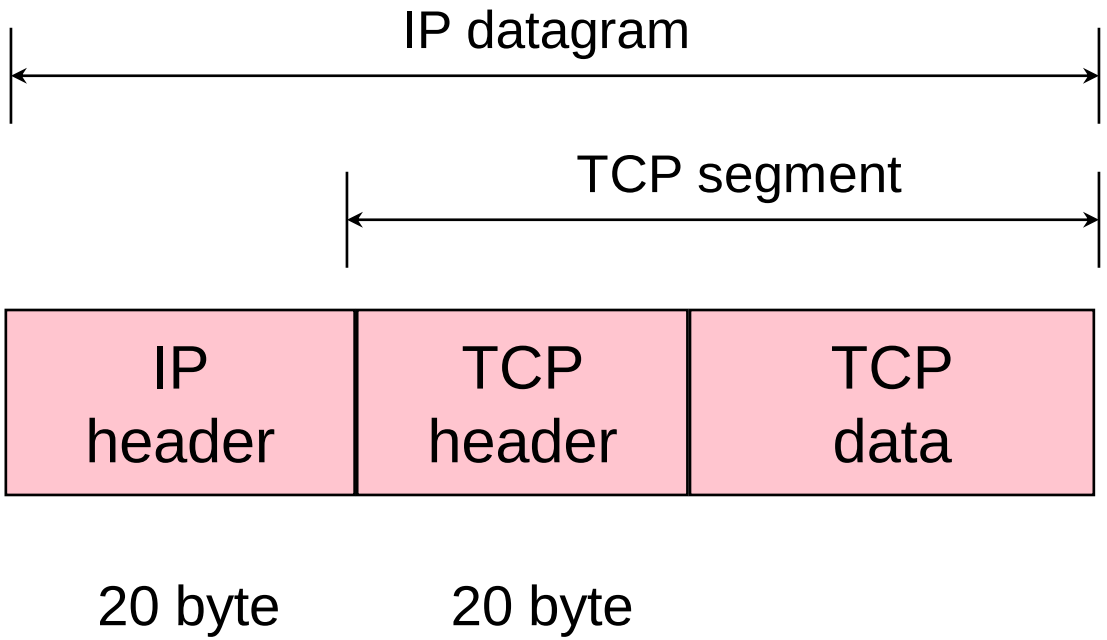
TCP Overview

- Connection-oriented
- Byte-stream
  - app writes bytes
  - TCP sends *segments*
  - app reads bytes

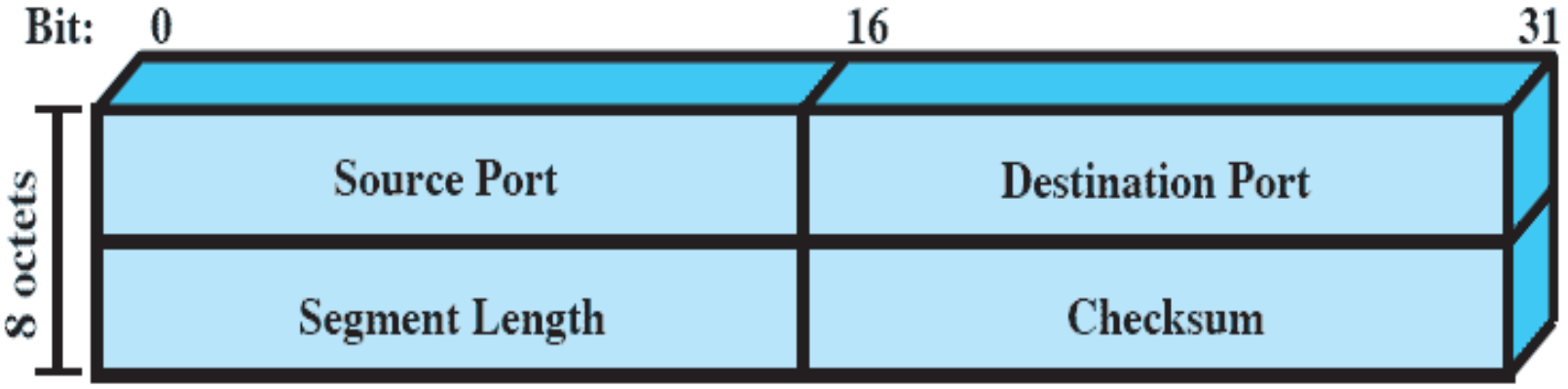
- Full duplex
- Flow control: keep sender from overrunning receiver
- Congestion control: keep sender from overrunning network



Strato di Trasporto: TCP



UDP



- minimum protocol mechanism
  - **connectionless**
  - no guarantees about delivery, preservation of sequence, nor protection against duplication
  - useful, e.g., for transaction-oriented applications
  - multicast support

Domain Name System (DNS)