SAPIENZA
UNIVERSITÀ DI ROMA

Network Infrastructures

A.A. 2020-2021
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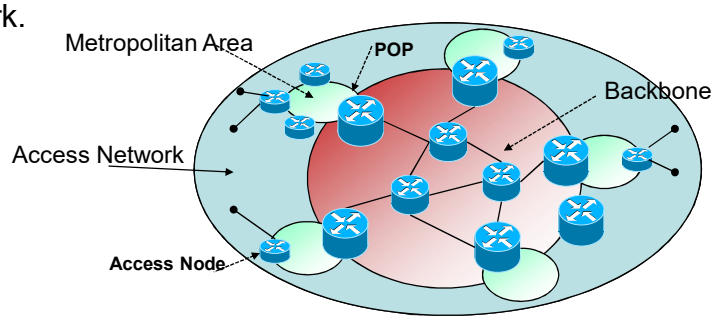
Network functional areas

Access network

- An access network is that part of a communications network which connects subscribers to their immediate service provider
- It is contrasted with the core network
- The access network may be further divided between feeder plant or distribution network, and drop plant or edge network.



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Access network

- The access network domain plays an important role in a network by connecting communications carriers and service providers with the individuals and companies they serve
- While communications carriers have historically used "**copper lines**" to offer phone service to individual subscribers, today the same line carries high-speed broadband services such as DSL (Digital Subscriber Loop or Digital Subscriber Line) in addition to telephone signals
- Carriers are also investing heavily in **optical fiber** as the transmission media for fixed broadband access
  - due to its high-speed and stable transmission characteristics

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Core Network

- A core network is a backbone network:
  - usually with a mesh topology
  - provides any-to-any connections among devices on the network
  - consists of multiple switches (e.g., ATM- Asynchronous Transfer Mode) or consists of IP routers
  - is constituted by an optical backbone
- The Internet could be considered a giant core network
  - it really consists of many service providers that run their own core networks, and those core networks are interconnected
- Significant to core networks is "the edge," where networks and users exist

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Edge of the network

- The edge may perform intelligent functions that are not performed inside the core network.
  - if the core network is using MPLS (Multiprotocol Label Switching), an edge switch may examine packets and select a path through the network based on various properties of the packet
- The core network then switches the packets (as opposed to doing hop-by-hop routing of the packets), which significantly improves performance
  - In this case, the core network is considered relatively "dumb" while the edge is considered "smart" because the path selection through the core is determined by the edge

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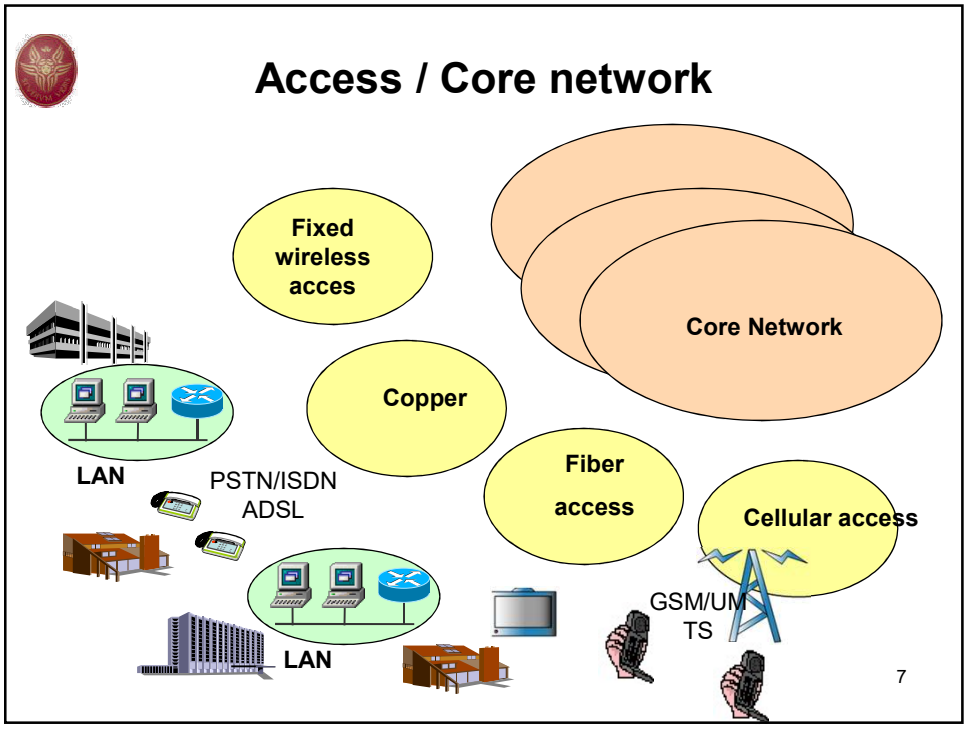
Access / Core network
Fixed wireless acces
Core Network
Copper
LAN
PSTN/ISDN
ADSL
Fiber access
Cellular access
GSM/UMTS
LAN
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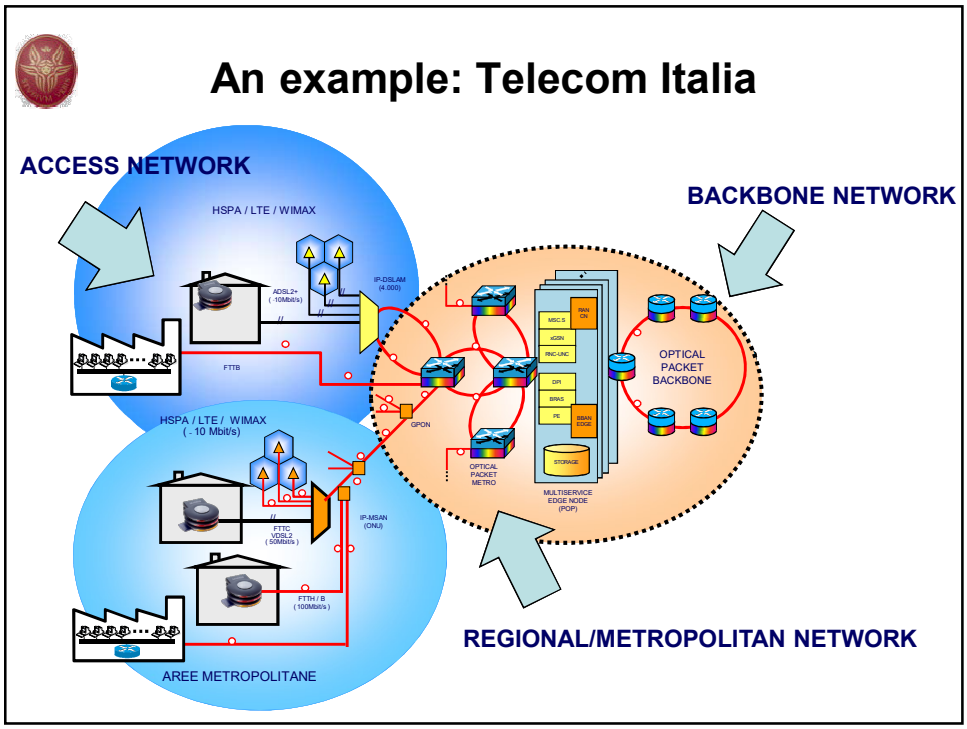
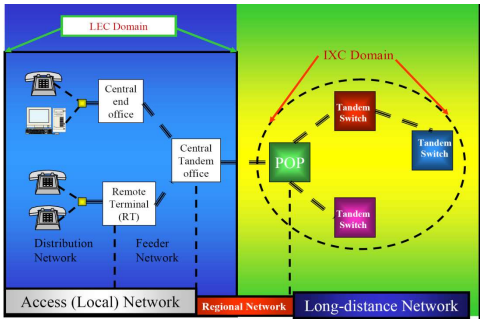

An example: Telecom Italia
ACCESS NETWORK
BACKBONE NETWORK
HSPA / LTE / WIMAX
ADSL2+
(10Mbit/s)
IP-DSLAM
(4.000)
FTTB
HSPA / LTE / WIMAX
(- 10 Mbit/s)
FTTC
VDSL2
(50Mbit/s)
IP-MSAN
(ONU)
FTTH / B
(100Mbit/s)
AREE METROPOLITANE
GPON
OPTICAL PACKET METRO
MULTISERVICE EDGE NODE (POP)
OPTICAL PACKET BACKBONE
REGIONAL/METROPOLITAN NETWORK

Network Terms

- Exchange Area
  - Local vs long distance
- LEC – Local Exchange Carrier
- ILEC – Incumbent LEC
- CLEC - Competitive LEC
- Trunks – fiber optical
- CO - Central Office
- LATA – Local access and transport area
- IXC – Inter-exchange Carrier
  - Carry inter-LATA traffic



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Some examples

Distribution frame where the copper pairs are connected one-by-one to the Central Office

Where all devices are hosted

Collocation space to permit CLECs to locate equipment in the central office

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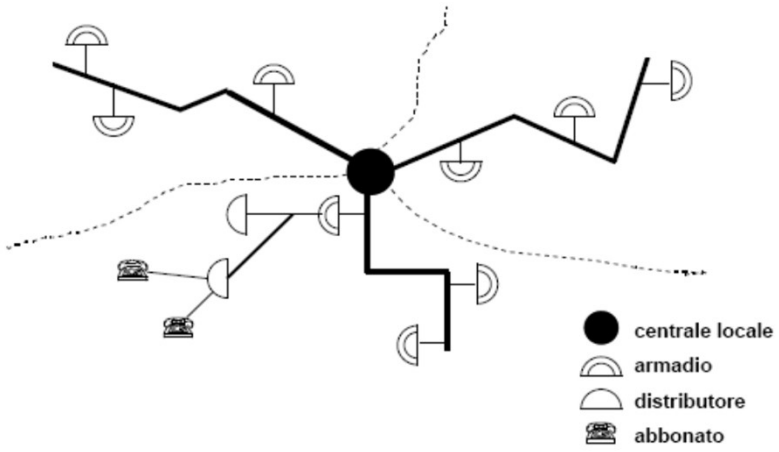
Distribution network



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Telecom Italia access Network

	Quantità	Unità misura
Borchia d'utente	33.576.000	Numero di borchie
Distributore	3.893.000	Numero di distributori
Armadio ripartilinea	142.500	Numero di armadi
Cavi a coppie simmetriche	105.700.000	km - circuito
Cavi (tracciato)	575.000	km
Palificazioni	8.893.000	Numero di pali
Infrastrutture di posa	20.000	km - tubazioni

Fonte: Telecom Italia 2007

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Fixed Line Access Network

- An access network refers to the series of wires, cables and equipments lying between a consumer/business telephone termination point (the point at which a telephone connection reaches the customer) and the local telephone exchange
- The local exchange contains banks of automated switching equipment to direct a call or connection to the consumer
- The access network is perhaps one of the oldest assets a telecom operator owns, and is constantly evolving, growing as new customers are connected, and as new services are offered
- This makes the access network one of the most complex networks in the world to maintain and keep track of

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Fixed Line Access Network

- The access network is also perhaps the most valuable asset an operator owns, since this is what physically allows them to offer a service
- Access networks consist largely of pairs of copper wires, each traveling in a direct path between the exchange and the customer
- Access networks around the world evolve to include more and more optical fiber technology
- Optical fiber already makes up the majority of core networks, and is now closer and closer to the customer (e.g., FTTH Fiber To The Home)

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Local loop

- In telephony, the local loop (also referred to as a subscriber line) is the physical link or circuit, that connects from the demarcation point of the customer premises to the edge of the carrier or telecommunications service provider, network.
- At the edge of the carrier network in a traditional PSTN (Public Switched Telephone Network) scenario, the local loop terminates in a circuit switch housed in an ILEC Central Office.

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Local loop

- Traditionally, the local loop was wireline in nature from customer to CO, specifically in the form of an electrical circuit (i.e., loop) provisioned as a single twisted pair in support of voice communications
- Modern implementations may include a digital loop carrier system segment or fiber optic transmission system known as fiber-in-the-loop
- The local loop may terminate at a circuit switch owned by a CLEC and housed in a POP, which typically is either an ILEC CO or a "carrier hotel"
- A local loop may be provisioned to support data communications applications, or combined voice and data such as digital subscriber line (DSL)

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Local loop

- Local loop connections can be used to carry a range of services, including:
  - analog voice and signaling used in traditional POTS
  - Integrated Services Digital Network (ISDN)
  - variants of Digital Subscriber Line (DSL)
- Many owners of local loops are public utilities that hold a natural monopoly
- To prevent the owner from using this natural monopoly to monopolize other fields of trade, some jurisdictions require utilities to **unbundle** the local loop, that is, make the local loop available to their competitors
- The term "local loop" is sometimes used for any "last mile" connection to the customer, regardless of technology or intended purpose. Hence the phrase "wireless local loop"

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Local loop

- Local loop connections include:
  - Electric local loop: PLC (power line communications)
  - Optical local loop: Fiber Optics services
  - Satellite local loop: communications satellite and cosmos Internet connections of satellite television (DVB-S- Digital Video Broadcasting-Satellite)
  - Cable local loop: Cable modem
  - Wireless local loop (WLL): LMDS, WiMAX, GPRS, HSDPA, DECT

LMDS: Local Multipoint Distribution Service
GPRS: General Packet Radio Service
HSDPA: High Speed Downlink Packet Access

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Type of access

- Copper access :
  - This domain provides both high-speed broadband and existing phone service.
    - » VDSL solutions that support high-speed broadband service
    - » phone migration solutions that can deliver existing phone service quality as a key infrastructure even as it evolves toward an IP network.

VDSL: Very High Digital Subscriber Line

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Copper based access network

- The major advantage of this network is that it is widely available
  - In industrialized countries there is almost universal access to this network, and in all countries the network can be accessed in the major cities
  - In those areas, use of existing infrastructure facilities is still very competitive in providing most types of services
  - In areas not covered by copper-based networks, use of other network technologies is likely to offer a cost efficient alternative
- The network is usually operated by the incumbent operator, which in many cases is fully or partly owned by the public
- The copper-based networks are established in markets with monopoly, and are therefore designed for covering the entire market
- Efforts have been made to introduce competition through demands for unbundling of facilities and interconnection with other networks

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Copper based access network

- Existing copper-based networks have gradually been expanded during several decades and their architectures are not optimized with regard to use of current technologies
- If an entirely new network were to be built today, it would not be based on use of copper-based technologies, and the design would therefore be very different from those of today's copper-based networks operated by the incumbent operators
- One problem is that networks are designed mainly for carrying POTS, while a growing share of the traffic is based on IP or other data communication protocols, and in some areas there are problems with capacity and quality of service.

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Cost analysis

- Access costs constitute 35-50% of the total network costs.
- Here the major cost driver is total cable length, which again depends on the number of connections and the density of customers.
- It may cost as much as five times more to connect customers in rural areas than in metropolitan areas.
- A major part of the costs are related to the laying of cables underground. Here substantial savings can be obtained through the use of ducts that can be shared between several cables.
- The digging costs are highly dependent on the geo-types.
  - it should be noted that digging costs per km often are much higher in metropolitan areas than in the open land.

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Cost analysis

- The costs of copper-based networks are affected by the following technological advances:
  - Today the copper-based trunk network is replaced by an optical network, while the access network is still based on copper lines. Installation of fibers has reduced the cost of capacity in trunk networks considerably
  - Digitalization of switching facilities and use of packet switched transmission technologies has reduced switching costs.
  - Implementation of Next Generation Access Network technologies will reduce transmission costs even further
  - Altogether these trends imply that the cost of the copper-based access network constitutes a still larger share of the total network costs

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Cost analysis

- However, technological advances are also taking in this part of the network.
- Alternative access networks offering lower costs or higher capacity have been developed.
- In areas where investments in copper-based access networks have already been made, the development of technologies offering more capacity on existing access facilities is at least as important.
- It is possible to upgrade the copper-based access networks to carry high-speed services through the use of xDSL technologies; the possible capacity depends on the length of the copper cables and the quality of the network.
- The bandwidths offered here range from 128 kbps to 10 Mbps.

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Cost analysis

- xDSL is the most widespread access technology for broadband access as 57% of all broadband connections use xDSL (end 2003).
- Provision of higher bandwidth will often, but not always, require more investments in the access network, and of course more capacity in the core network.
- By all means, the capacity is much lower than in optical networks.
- On the other hand, the additional investments needed for upgrading the network are only a fraction of what is needed for the establishment of an optical network.

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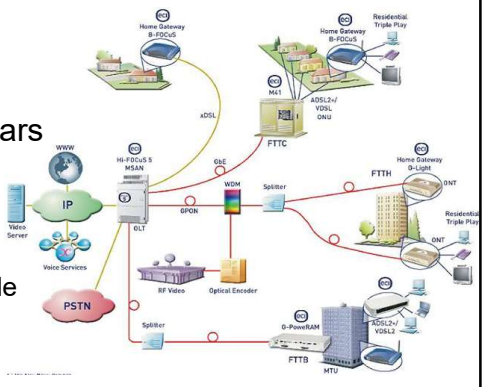
Type of access

- Optical access :
  - This domain will be the mode of choice for fixed access in the coming years
    - » GE-PON (individual),
    - » GPON (enterprise),
    - » and COF (long-distance)
    - » represent systems capable of delivering ultra-high-speed, high-reliability performance.



GE: Gigabit Ethernet
PON: Passive Optical Network
COF: Code Division Multplexing over Fiber

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FTTx = Fiber-to-the-x

- FTTH - Home
- FTTC - Curb
- FTTN - Node or Neighborhood
- FTTP - Premise
- FTTB - Building or Business
- FTTU - User
- FTTZ - Zone
- FTTO - Office
- FTTD - Desk

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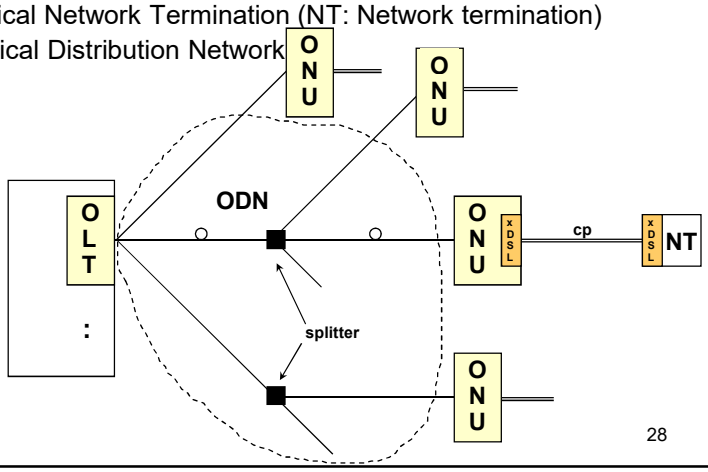
FTTx: reference architectures

- FTTx elements:
  - OLT: Optical Line Terminal
  - ONU: Optical Network Unit
  - ONT: Optical Network Termination (NT: Network termination)
  - ODN: Optical Distribution Network



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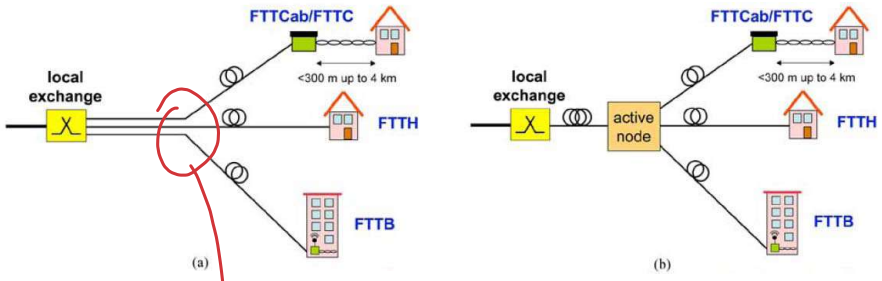
FTTx: reference architectures

- **AON (Active Optical Network),** *also called Point-to-Point (P2P)*



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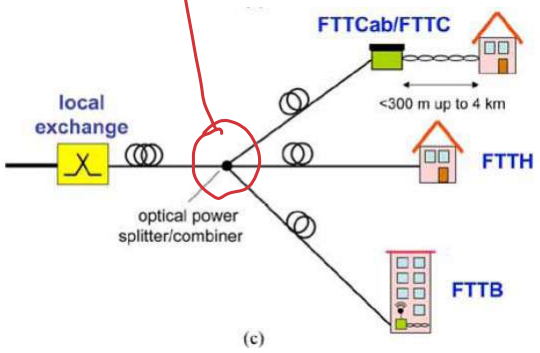
FTTx: reference architectures

- **PON (Passive Optical Network)**: passive branching of fibes via optical spiltters and tree-based topologies



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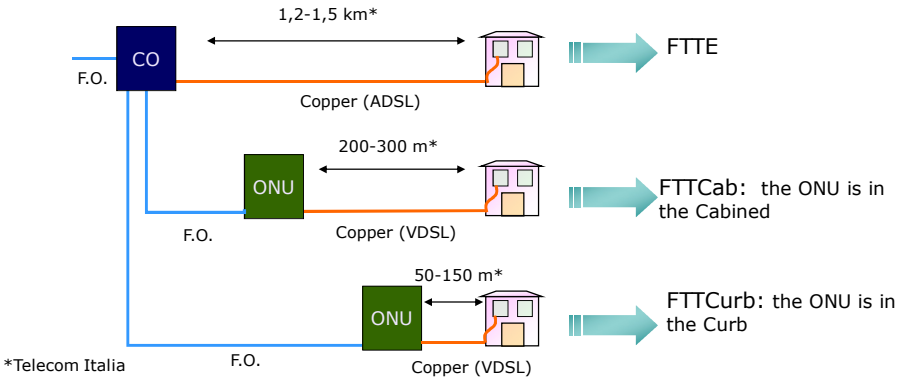
- **Fiber to the Exchange:** the optical fiber terminates to the Central Office (CO) and the CO is connected with the user via a copper based line (e.g., ADSL)



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Cub/Curb – Distribution network






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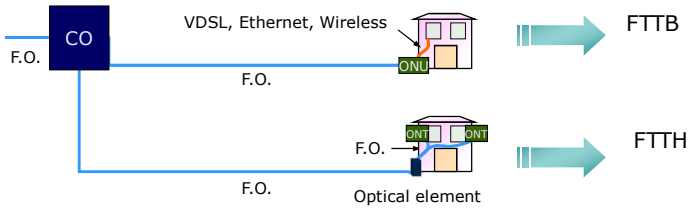
FTTP/FTTB/FTTH

- **Fiber to the Premises** the fiber cables arrive to the users'premises
  - **Fiber to the Building**
  - **Fiber to the Home**



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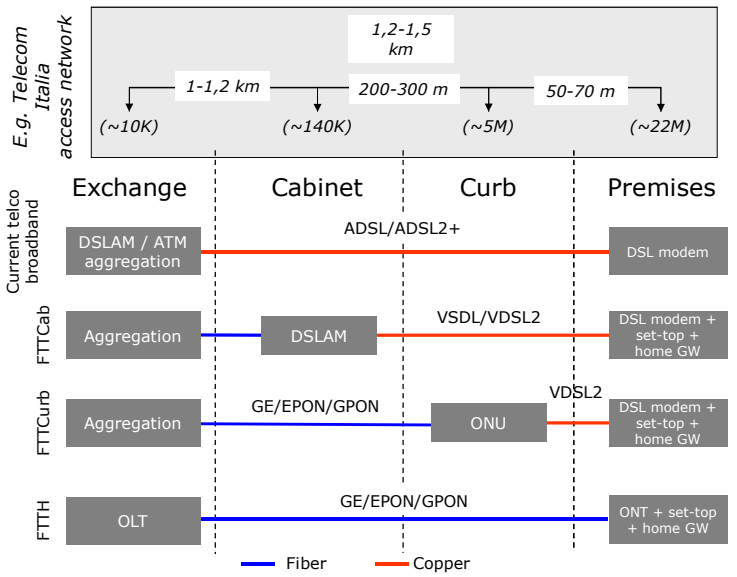
Wireline access



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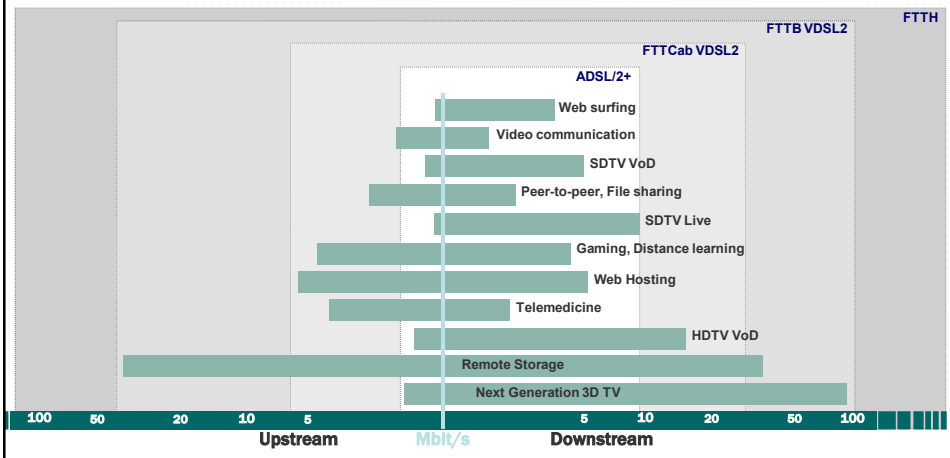
Bandwidth requirements



Source:Telecom Italia

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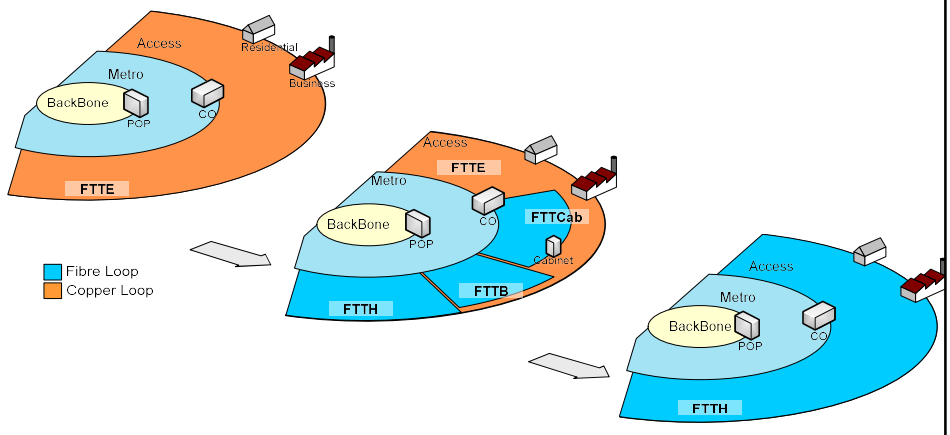
Fiber based access network



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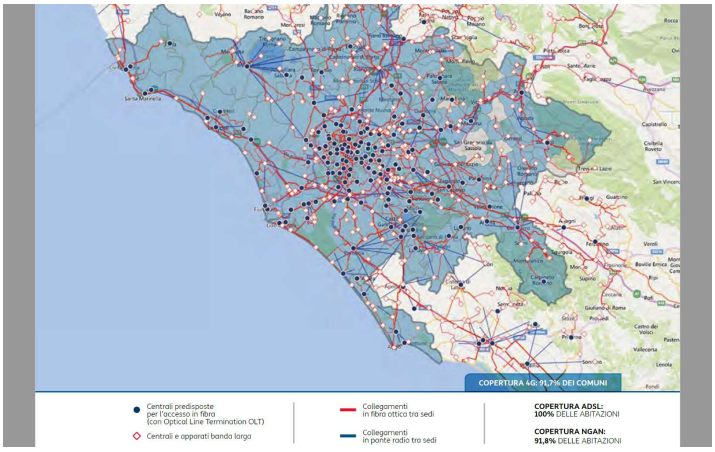
Numbers today

- Open data available at https://rete.gruppotim.it/



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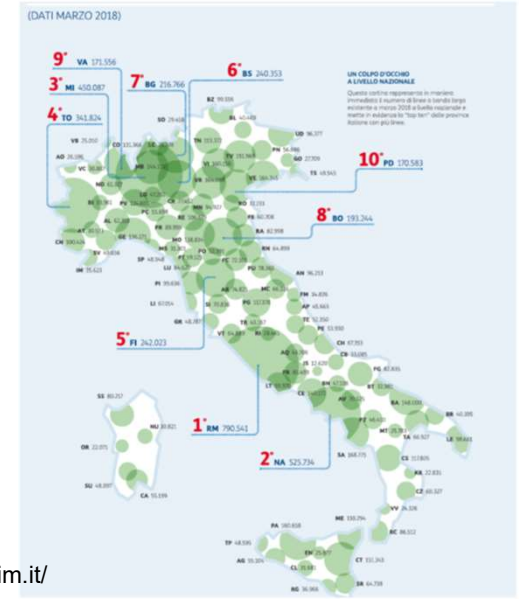
Broadband access Italy 2018



https://rete.gruppotim.it/

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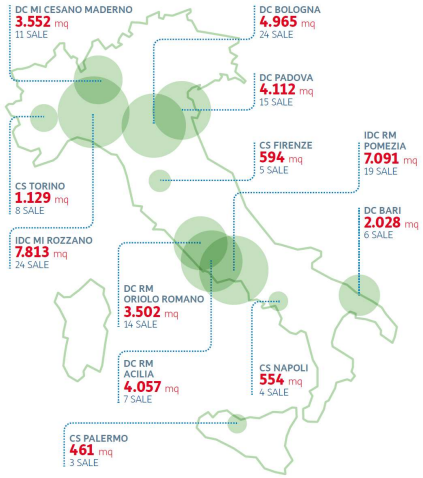
Cloud computing



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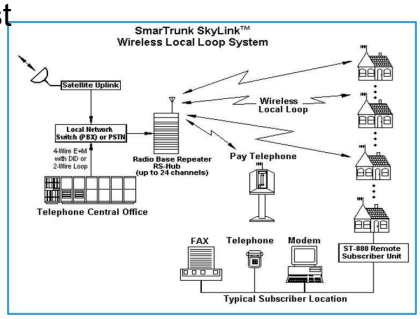
Type of access

- Wireless access :
  - This domain enjoys the highest expectations from the standpoint of ubiquitous networking
    - » WLL
    - » 3G mobile networking
    - » WiMAX solutions
    - » support seamless communications and high-speed broadband service, providing both fixed and mobile access in a single system



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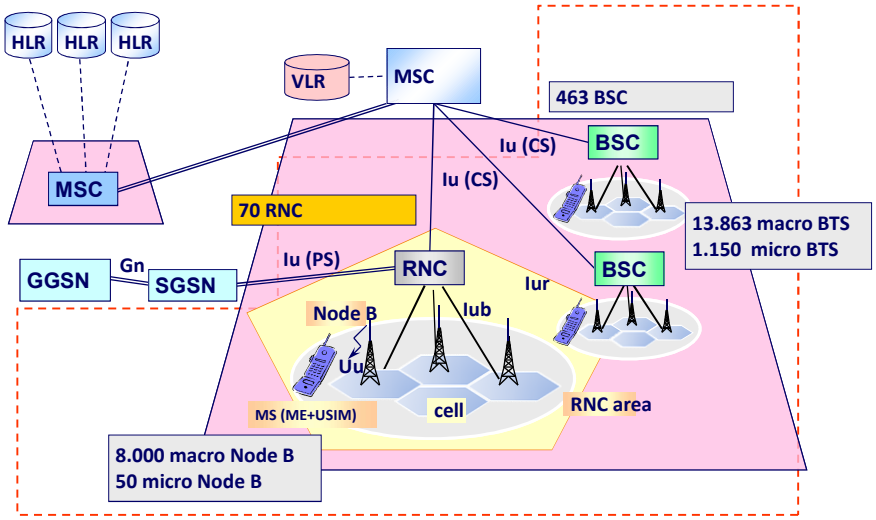
2G and 3G architecture



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GSM network

	Quantità	Unità misura
Siti per antenne radiomobili	14.000	Siti dei tralicci
Stazioni radio BTS	13.865	Numero stazioni radio
Controllori stazione BSC	463	Numero di BSC
Trasmettitori	90.090	Numero di TXT
Celle	24.522 (900 MHz) – 7.551 (1800 MHz)	Numero di celle
Canali	556.264 (900 MHz) – 164.458 (1800 MHz)	Numero di canali
Frequenze	12 (900 MHz) – 15 (1800 MHz)	MHz

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3G network

	Quantità	Unità misura
Siti per antenne UMTS	8.030	Siti dei tralicci
Stazioni radio - Nodi B	8.030	Numero stazioni radio
Controllori stazione RNC	70	Numero di RNC
Celle	22.094	Numero di celle
Canali	834.752	Numero di canali
Frequenze	10 (2100 MHz)	MHz

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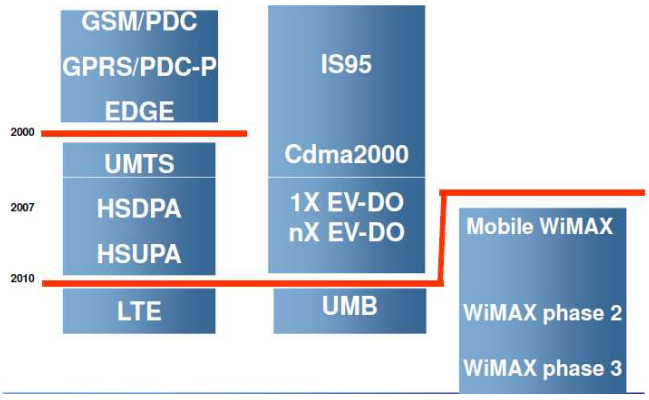
Wireless Access: cont'd



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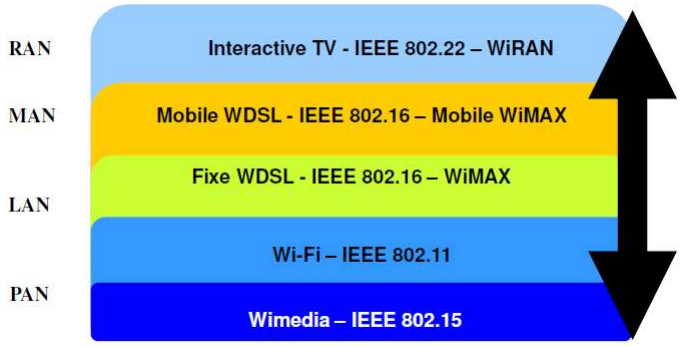
Wireless Access: cont'd



- As ubiquitous service-anytime, anywhere, anyone-becomes the norm, demand for technologies such as conventional cellular phone service and wireless LAN access is being augmented by an increasingly noticeable desire for mobile high-speed broadband service and otherwise seamless communications

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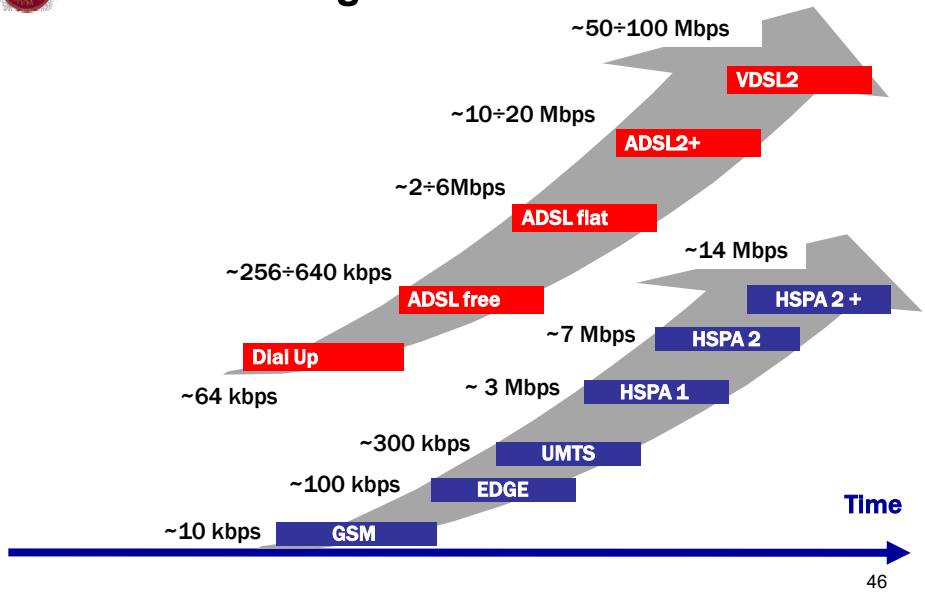
Techologies and bandwidths



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Backbone: the logical topology

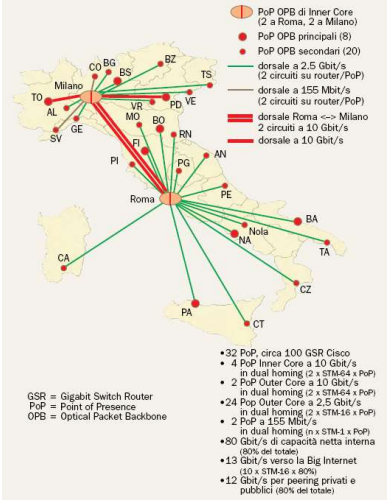
OPB (Optical Packet Backbone)

•32 PoP

•Inner Core: 4 PoP (2 in Rome,, 2 in Milan)

•Outer Core: 28 PoP

•Inner Core: 10 Gbit/s (STM-
•64)
•Outer Core: 10 Gbit/s (STM-64),
•2,5 Gbit/s (STM-16) and 155 Mbit/s (STM-1)
• Link used at 50%



Source: Telecom Italia

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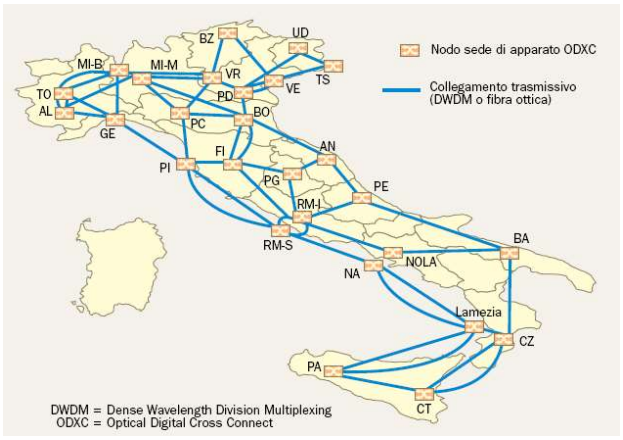
Backbone: the physical topology

Physical network build up on the Optical Transport Network



Source: Telecom Italia

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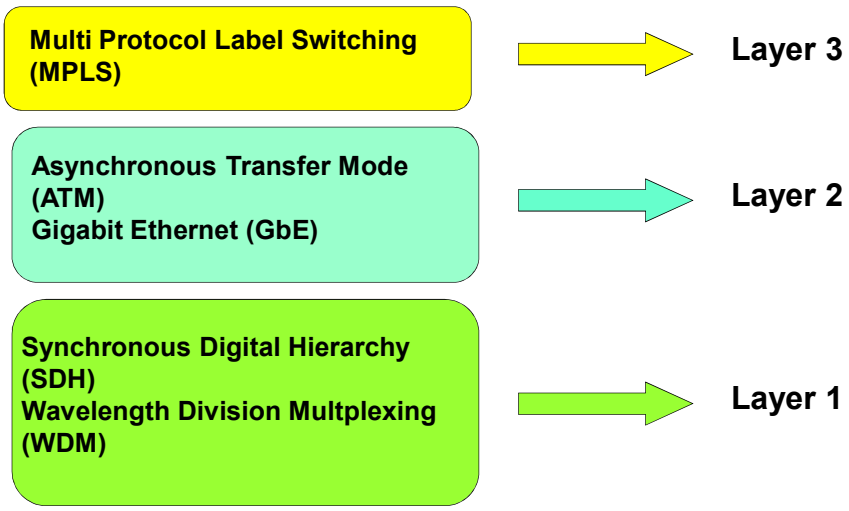
Technologies and protocols



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Towards the Next Generation Network

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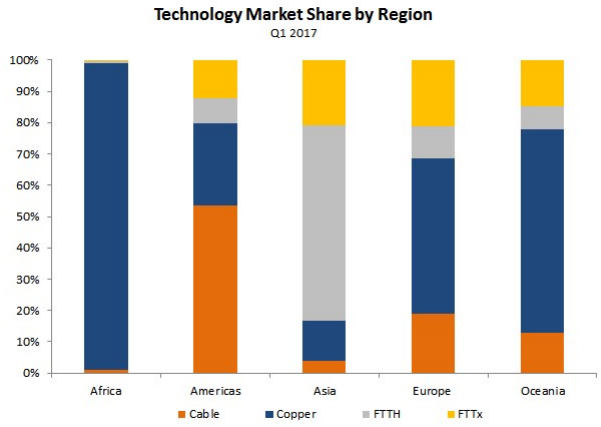
Some current statistics



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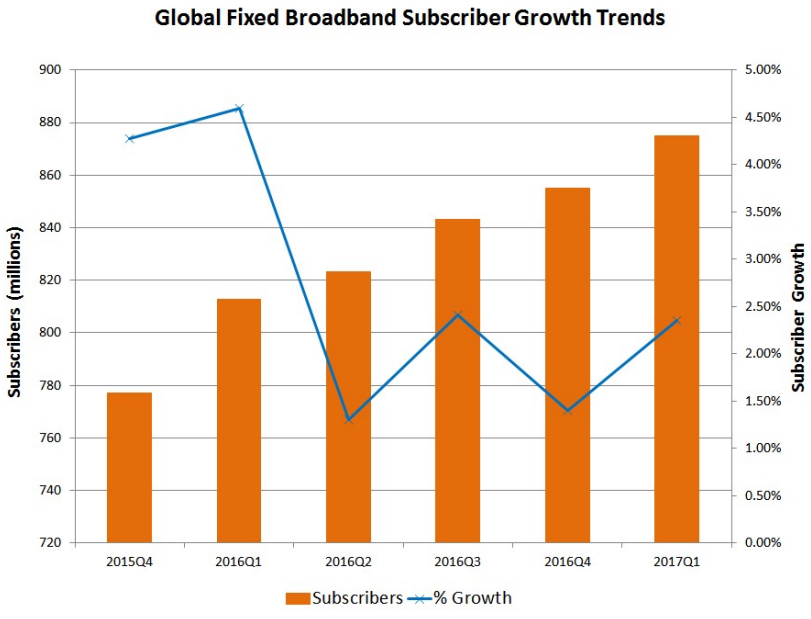
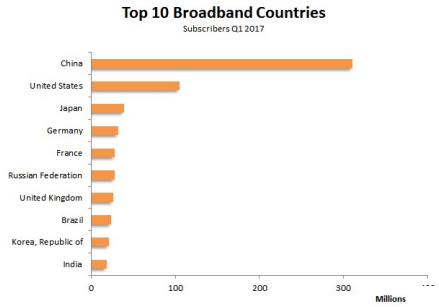
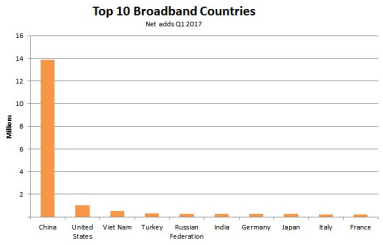


Broadband Countries





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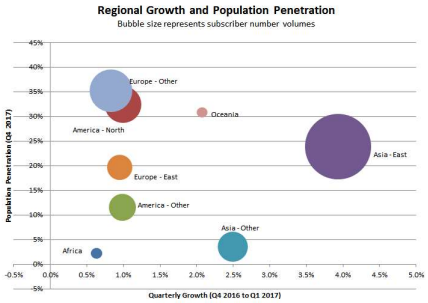
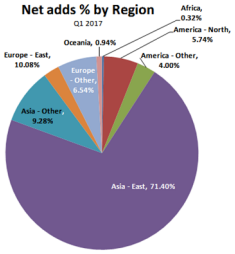
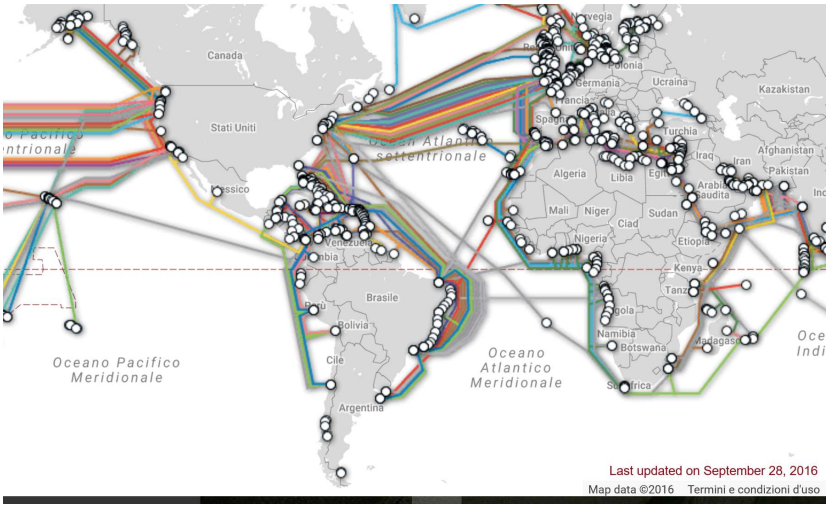
Regional growth





Examples of network infrastructures (http://www.submarinecablemap.com/)



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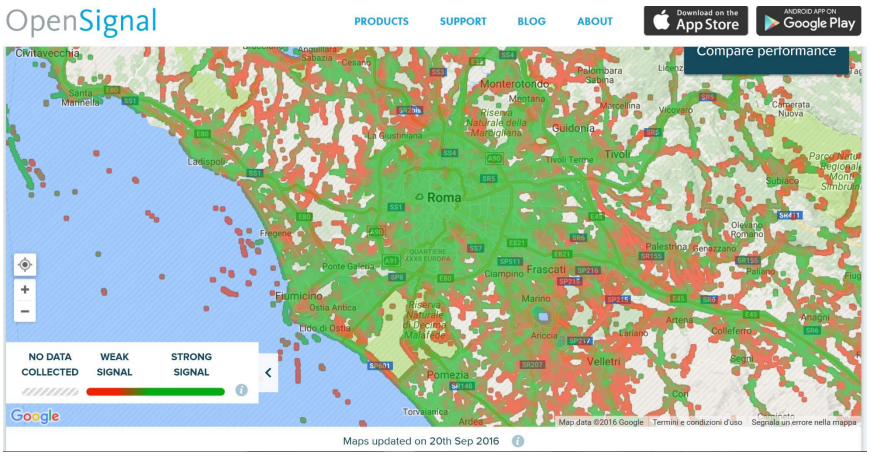
Examples of network infrastructures (http://opensignal.com/coverage-maps/Italy/



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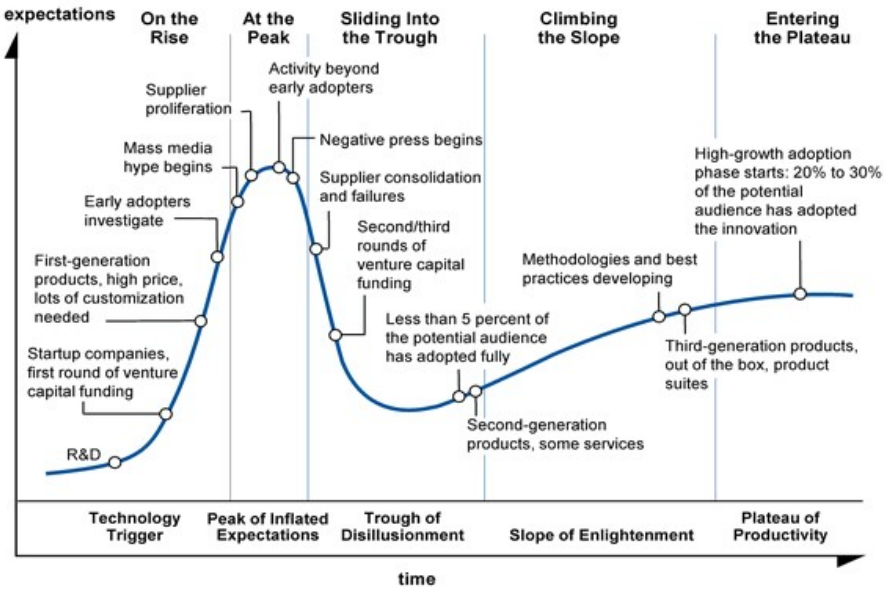
Gartner hype cycle



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