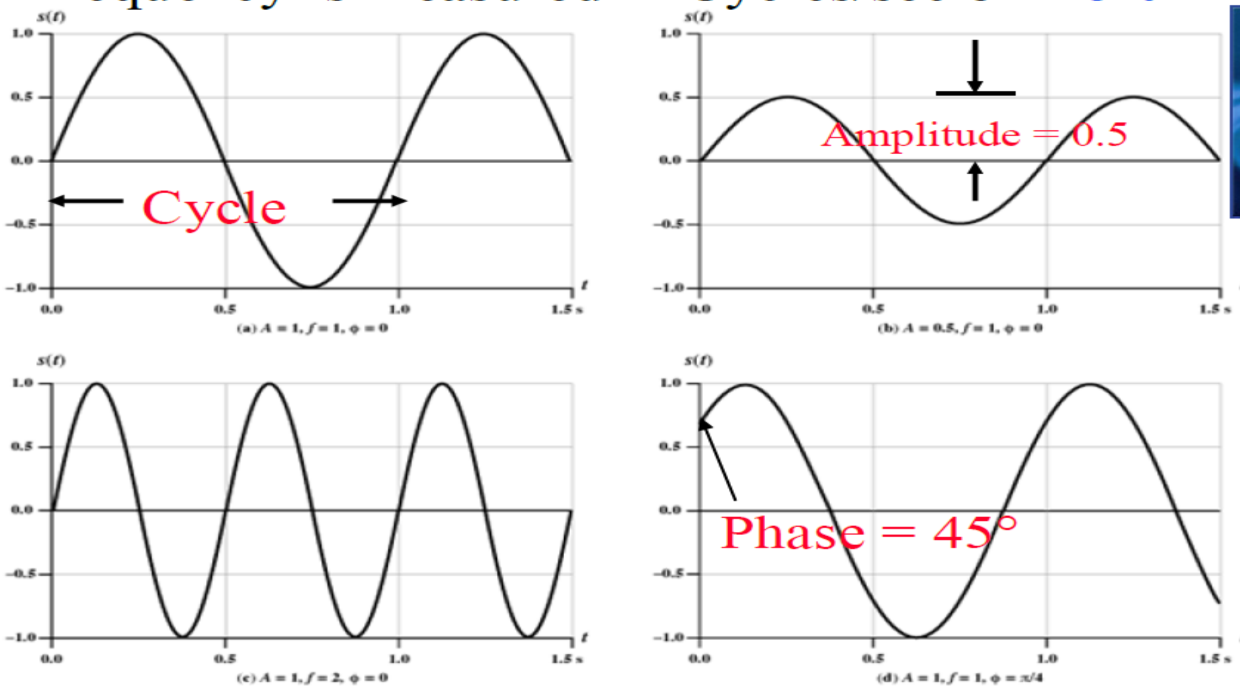
Meios Físicos

MC822 – Nelson Fonseca

Frequency, Period, and Phase

- A Sin(2πft + θ), A = Amplitude, f=Frequency,
  θ = Phase, Period T = 1/f,
  Frequency is measured in Cycles/sec or **Hertz**

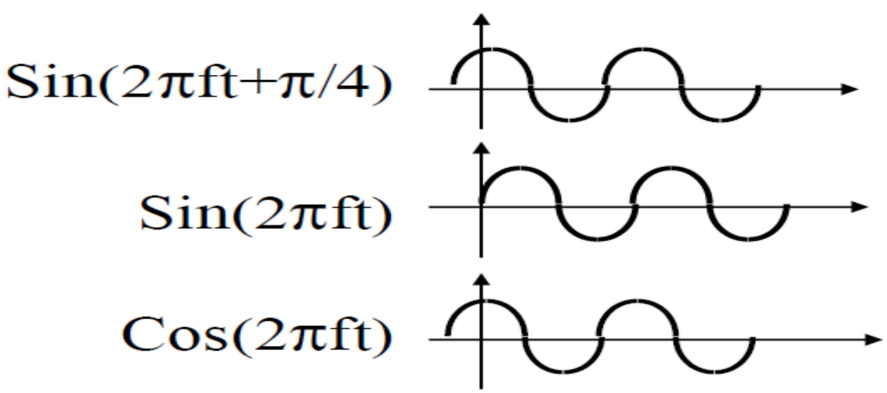


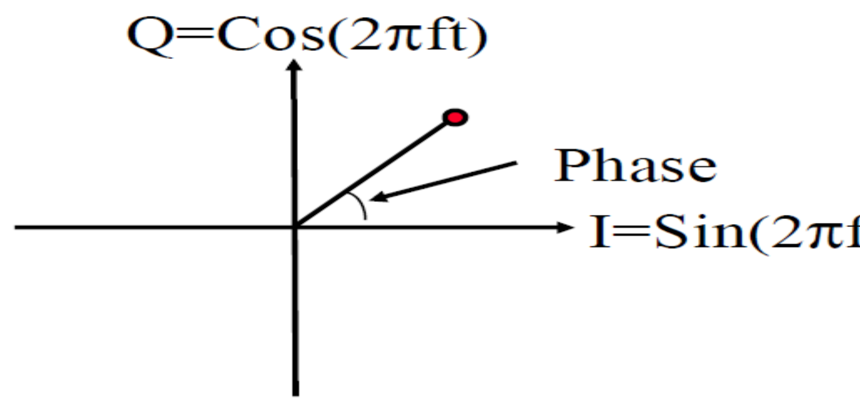
Phase

- Sine wave with a phase of 45°

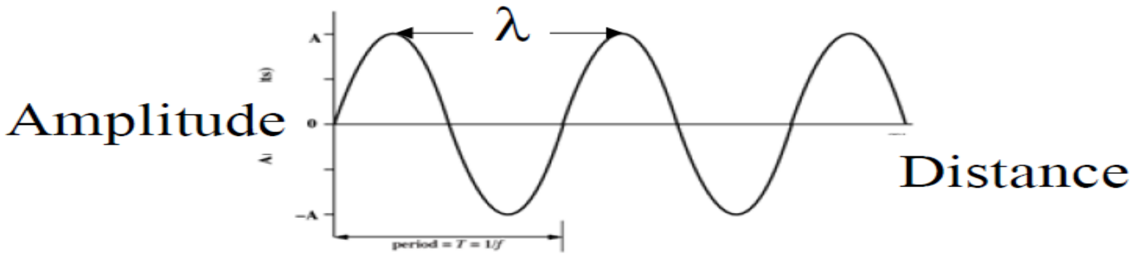
$$\begin{aligned}\sin(2\pi f t + \frac{\pi}{4}) &= \sin(2\pi f t)\cos(\frac{\pi}{4}) + \cos(2\pi f t)\sin(\frac{\pi}{4}) \\ &= \frac{1}{\sqrt{2}}\sin(2\pi f t) + \frac{1}{\sqrt{2}}\cos(2\pi f t)\end{aligned}$$

In-phase component I + Quadrature component Q





Wavelength



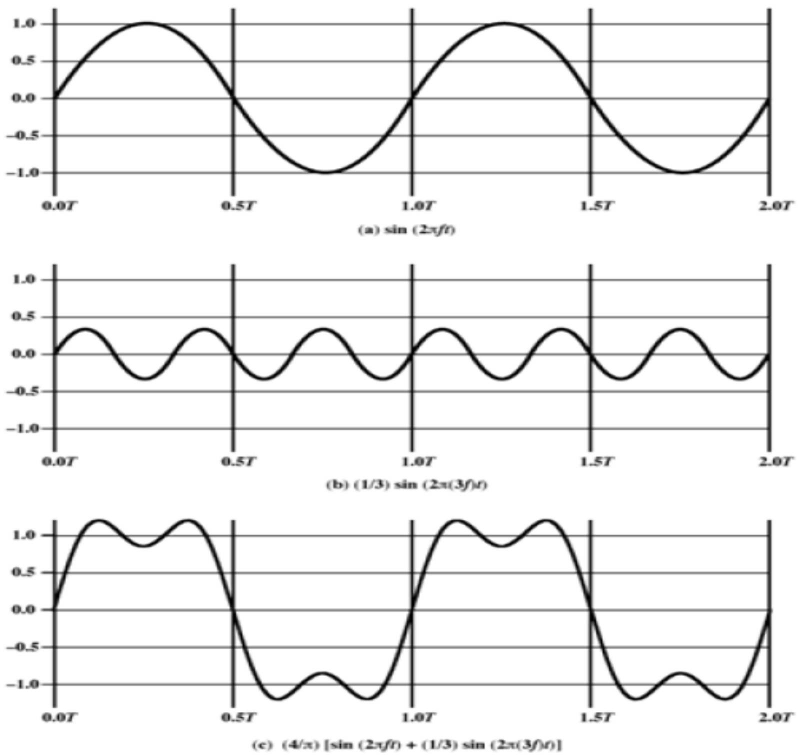
- Distance occupied by one cycle
- Distance between two points of corresponding phase in two consecutive cycles
- Wavelength = λ
- Assuming signal velocity v
  - $\lambda = vT$
  - $\lambda f = v$
  - c = 3×10^8 m/s (speed of light in free space) = *300 m/μs*

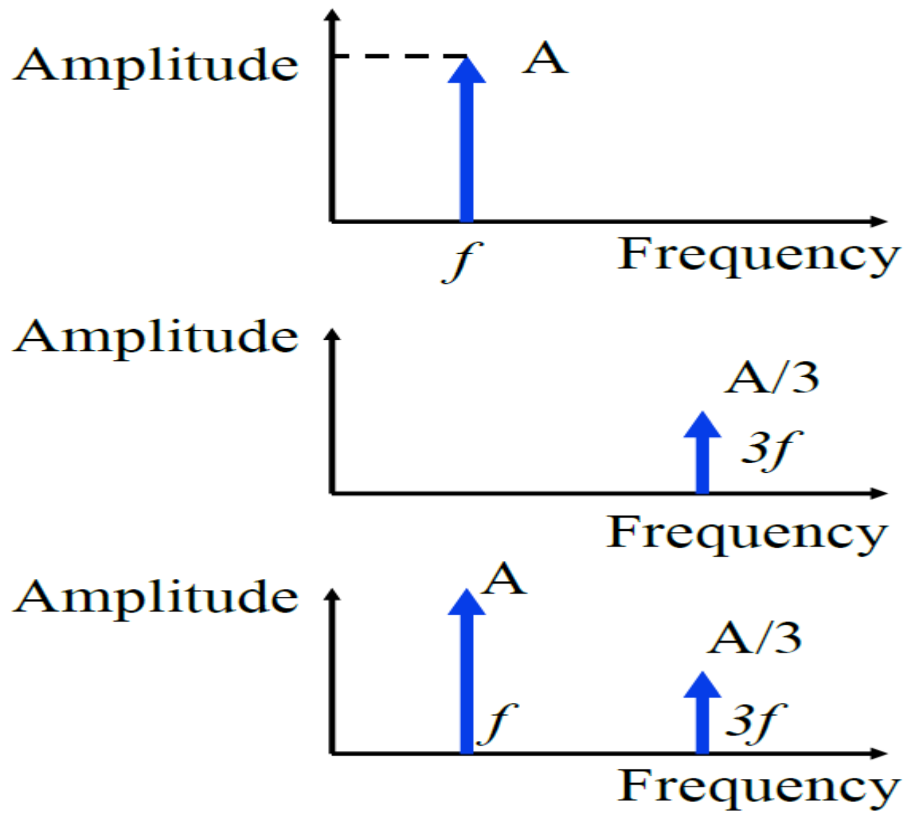
Example

- Frequency = 2.5 GHz

$$
\begin{aligned}
\text{Wavelength } = \lambda &= \frac{c}{f} \\
&= \frac{300 \text{ m}/\mu\text{s}}{2.5 \times 10^9} \\
&= 120 \times 10^{-3} = 120 \text{ mm} = 12 \text{ cm}
\end{aligned}
$$

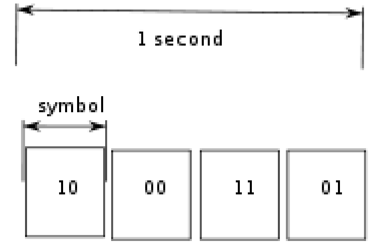
Time and Frequency Domains



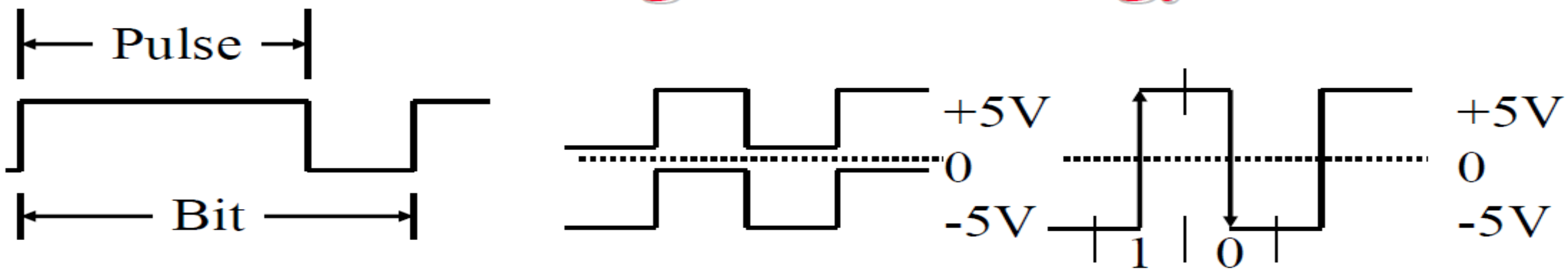


Decibels

- Attenuation = $\log_{10} \dfrac{P_{in}}{P_{out}}$ Bel
- Attenuation = $10 \log_{10} \dfrac{P_{in}}{P_{out}}$ decibel
- Attenuation = $20 \log_{10} \dfrac{V_{in}}{V_{out}}$ decibel
- **Example 1**: Pin = 10 mW, Pout=5 mW
  Attenuation = $10 \log_{10} (10/5) = 10 \log_{10} 2 = 3$ dB
- **Example 2**: Pin = 100mW, Pout=1 mW
  Attenuation = $10 \log_{10} (100/1) = 10 \log_{10} 100 = 20$ dB



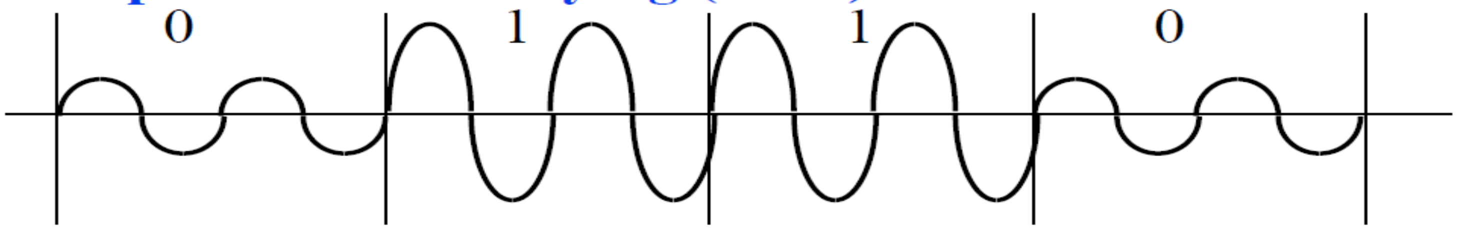
Coding Terminology



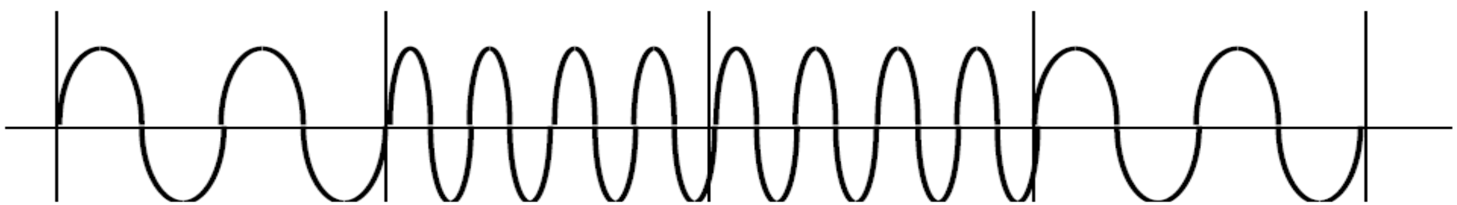
- **Signal element**: Pulse (of constant amplitude, frequency, phase) = **Symbol**
- **Modulation Rate**: 1/Duration of the smallest element =Baud rate
- **Data Rate**: Bits per second

Modulation

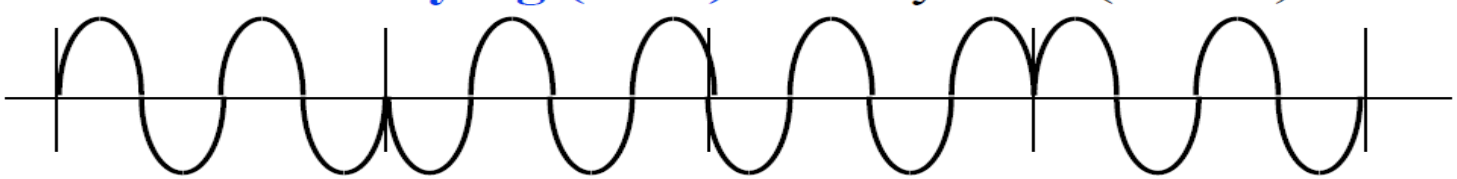
- Digital version of modulation is called **keying**
- **Amplitude Shift Keying (ASK):**



- **Frequency Shift Keying (FSK):**

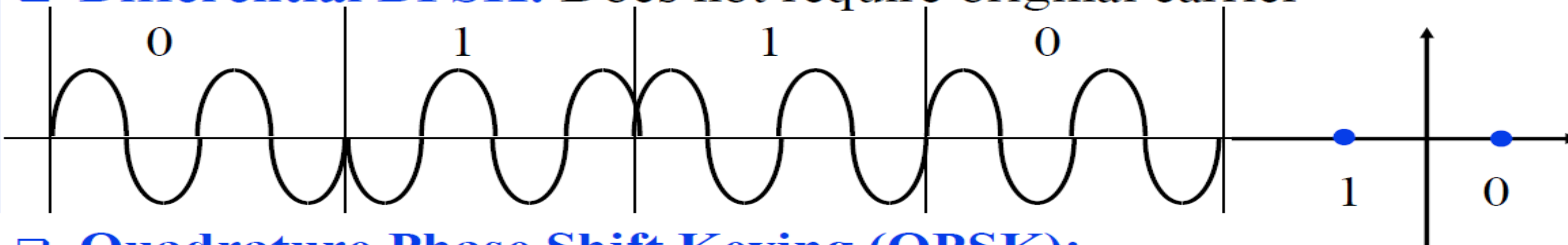


- **Phase Shift Keying (PSK):** Binary PSK (BPSK)

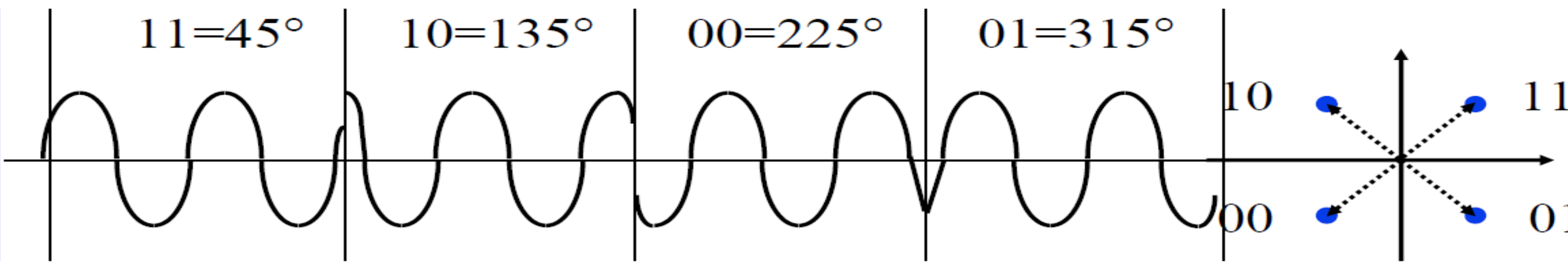


Modulation (Cont)

- **Differential BPSK:** Does not require original carrier



- **Quadrature Phase Shift Keying (QPSK):**

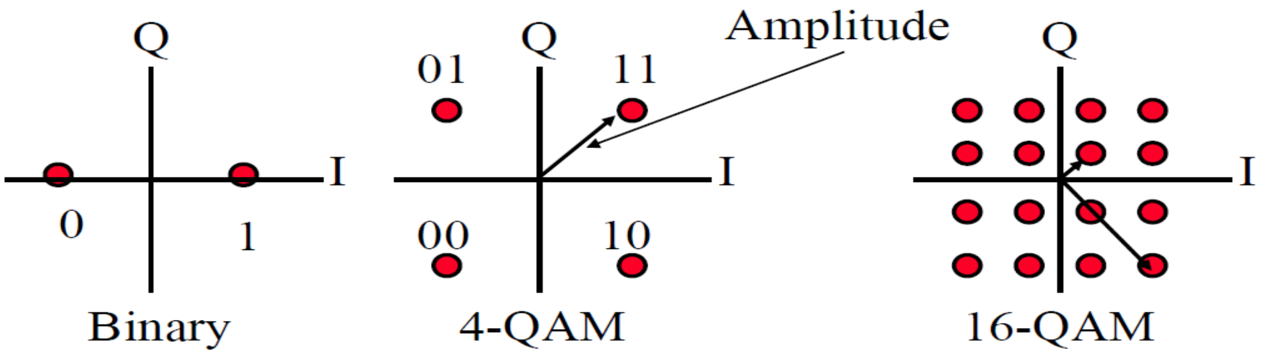


- In-phase (I) and Quadrature (Q) or 90 ° components are added

Ref: Electronic Design, "Understanding Modern Digital Modulation Techniques," http://electronicdesign.com/communications/understanding-modern-digital-modulation-techniques

QAM

- Quadrature Amplitude and Phase Modulation
- 4-QAM, 16-QAM, 64-QAM, 256-QAM
- Used in DSL and wireless networks



- 4-QAM$\Rightarrow$ 2 bits/symbol, 16-QAM $\Rightarrow$4 bits/symbol, …

The most common digital modulation techniques are:

- Phase-shift keying (PSK)
    - Binary PSK (BPSK), using M=2 symbols
    - Quadrature PSK (QPSK), using M=4 symbols
    - 8PSK, using M=8 symbols
    - 16PSK, using M=16 symbols
    - Differential PSK (DPSK)
    - Differential QPSK (DQPSK)
    - Offset QPSK (OQPSK)
    - π/4–QPSK
- Frequency-shift keying (FSK)
    - Audio frequency-shift keying (AFSK)
    - Multi-frequency shift keying (M-ary FSK or MFSK)
    - Dual-tone multi-frequency (DTMF)
- Amplitude-shift keying (ASK)
- On-off keying (OOK), the most common ASK form
    - M-ary vestigial sideband modulation, for example 8VSB
- Quadrature amplitude modulation (QAM), a combination of PSK and ASK
    - Polar modulation like QAM a combination of PSK and ASK[citation needed]
- Continuous phase modulation (CPM) methods
    - Minimum-shift keying (MSK)
    - Gaussian minimum-shift keying (GMSK)
    - Continuous-phase frequency-shift keying (CPFSK)
- Orthogonal frequency-division multiplexing (OFDM) modulation
    - Discrete multitone (DMT), including adaptive modulation and bit-loading
- Wavelet modulation
- Trellis coded modulation (TCM), also known as Trellis modulation
- Spread-spectrum techniques
    - Direct-sequence spread spectrum (DSSS)
    - Chirp spread spectrum (CSS) according to IEEE 802.15.4a CSS uses pseudo-stochastic coding
    - Frequency-hopping spread spectrum (FHSS) applies a special scheme for channel release

WiFi Modulation

WiFi systems use two primary radio transmission techniques.

- **802.11b (<=11 Mbps)** – The 802.11b radio link uses a direct sequence spread spectrum technique called **complementary coded keying** (CCK). The bit stream is processed with a special coding and then modulated using Quadrature Phase Shift Keying (QPSK).
- **802.11a and g (<=54 Mbps)** – The 802.11a and g systems use 64-channel orthogonal frequency division multiplexing (OFDM). In an OFDM modulation system, the available radio band is divided into a number of sub-channels and some of the bits are sent on each. The transmitter encodes the bit streams on the 64 subcarriers using Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), or one of two levels of Quadrature Amplitude Modulation (16, or 64-QAM). Some of the transmitted information is redundant, so the receiver does not have to receive all of the sub-carriers to reconstruct the information.

The original 802.11 specifications also included an option for frequency **hopping spread spectrum** (FHSS), but that has largely been abandoned.

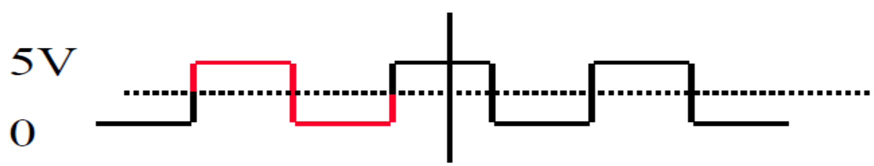
Adaptive Modulation

WiFi uses adaptive modulation and varying levels of forward error correction to optimize transmission rate and error performance.

As a radio signal loses power or encounters interference, the error rate will increase. Adaptive modulation means that the transmitter will automatically shift to a more robust, though less efficient, modulation technique in those adverse conditions.

Channel Capacity

- Capacity = Maximum data rate for a channel
- **Nyquist Theorem**: Bandwidth = B
  Data rate $\leq$ 2 B
- Bi-level Encoding: Data rate = 2 $\times$ Bandwidth



- Multilevel: Data rate = 2 $\times$ Bandwidth $\times \log_2 M$

Example: M=4, Capacity = 4 $\times$ Bandwidth

(3) The Nyquist Limit

For a noiseless channel, the maximum data rate is:

$$2H \log_2 V \text{ bits/sec}$$

,where H is the channel bandwidth (in Hz) and V is the number of discrete levels of the signal.

(4) The Shannon Limit

The maximum data rate of a noisy channel whose bandwidth is *H* Hz, and whose signal-to-noise ratio is *S/N*, is given by

$$H \log_2 (1+S/N).$$

Shannon's Theorem

- Bandwidth = B Hz
  Signal-to-noise ratio = S/N
- Maximum number of bits/sec = B $\log_2$ (1+S/N)
- Example: Phone wire bandwidth = 3100 Hz

$$S/N = 30 \text{ dB}$$

$$10 \text{ Log}_{10} S/N = 30$$

$$\text{Log}_{10} S/N = 3$$

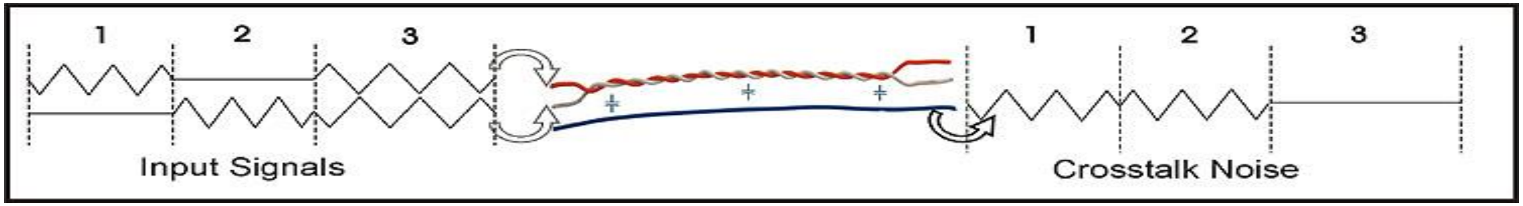
$$S/N = 10^3 = 1000$$

$$\text{Capacity} = 3100 \log_2 (1+1000)$$

$$= 30{,}894 \text{ bps}$$

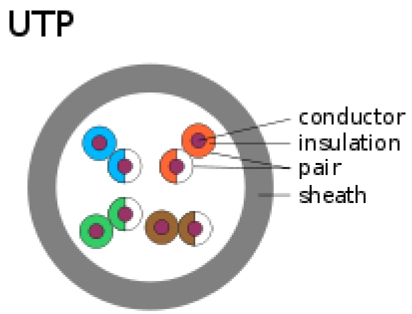
Par Trançado

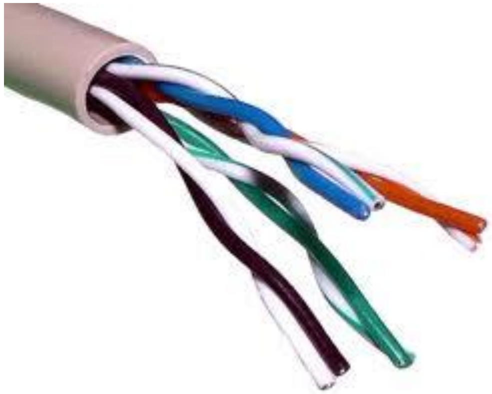
- Longas distâncias sem repetidores
- Banda passante depende do diâmetro do fio e distância percorrida
- Crosstalk e atenuação
- Usado em telefonia e redes ethernet
- Para transmissão de vídeo introduz skew – introdução de linhas de atraso



Par Trançado

- Categoria 3, 5, 6, 7 e 8
- UTP 25 pares

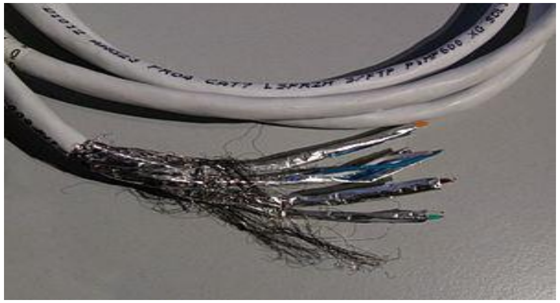




Par Trançado

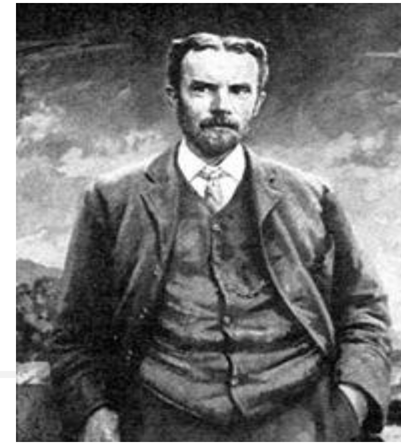
- Cat3 (16 MHz) 10BASE TX e 100BASET
- Cat5 (100 MHz) 100BASE TX e 1000BASET
- Cat 6 (250 MHz) 1000Base T (1 Gbps)
- Cat 6e 10000Base T (10 gbps)
- CAT7 (10Gbps) e CAT7a (40 Gbps)
- CAT8 40 Gbps (em desenvolvimento)
- Distância máxima – 100 metros

Par Trançado



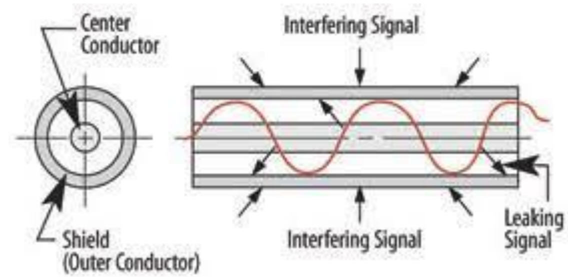
UTP Categories - Copper Cable				
UTP Category	**Data Rate**	**Max. Length**	**Cable Type**	**Application**
CAT1	Up to 1Mbps	-	Twisted Pair	Old Telephone Cable
CAT2	Up to 4Mbps	-	Twisted Pair	Token Ring Networks
CAT3	Up to 10Mbps	100m	Twisted Pair	Token Rink & 10BASE-T Ethernet
CAT4	Up to 16Mbps	100m	Twisted Pair	Token Ring Networks
CAT5	Up to 100Mbps	100m	Twisted Pair	Ethernet, FastEthernet, Token Ring
CAT5e	Up to 1 Gbps	100m	Twisted Pair	Ethernet, FastEthernet, Gigabit Ethernet
CAT6	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 10G Ethernet (55 meters)
CAT6a	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 10G Ethernet (55 meters)
CAT7	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 10G Ethernet (100 meters)

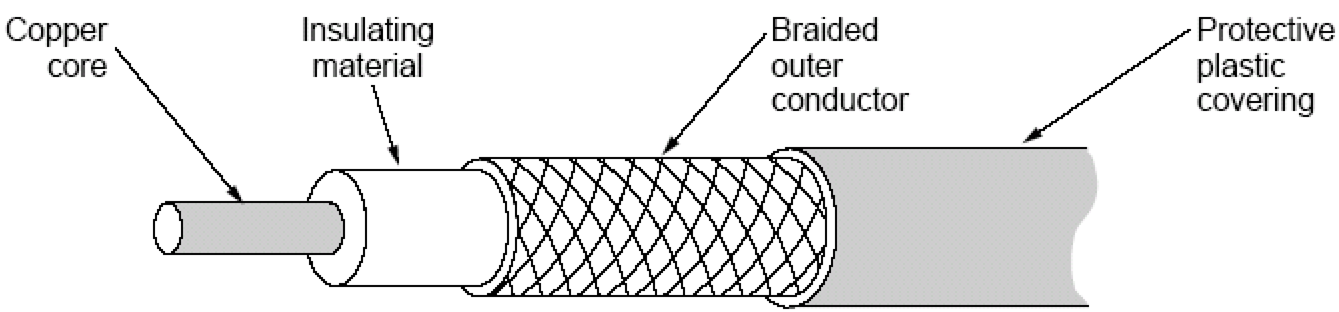
Cabo Coaxial



Oliver Heaviside

- Cabo Coaxial Banda Básica
  - 50 ohms
  - Transmissão digital

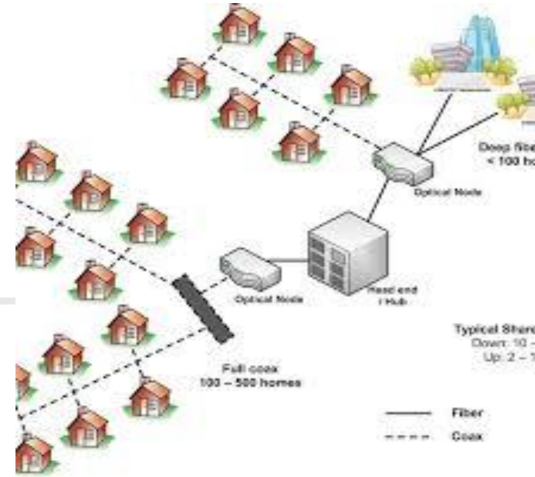




Cabo Coaxial

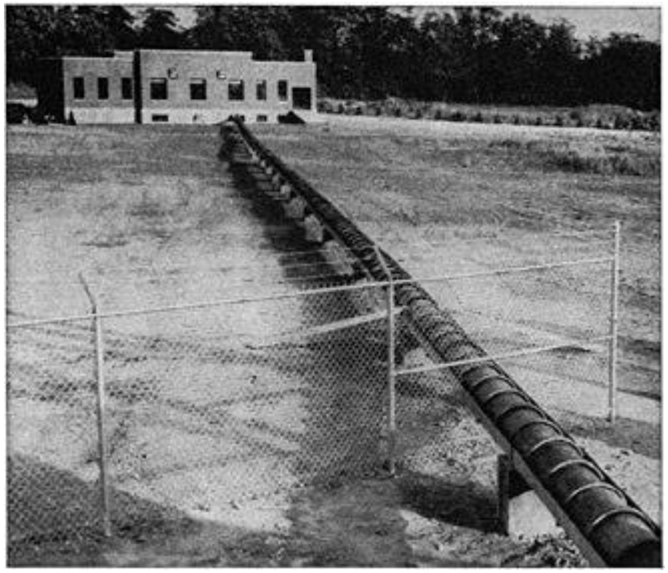
- Cabo Coaxial Banda Larga
  - 75 ohms
  - Transmissão analógica
  - TV a cabo, canais de 6 MHz - 3 Mbps
  - Repetidores transmitem em uma única direção: sistema com cabo duplo e sistema com cabo único

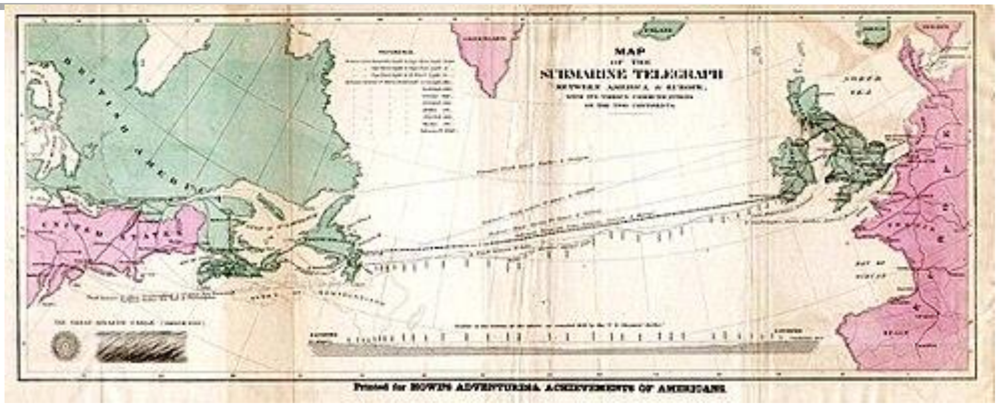
Cabo Coaxial

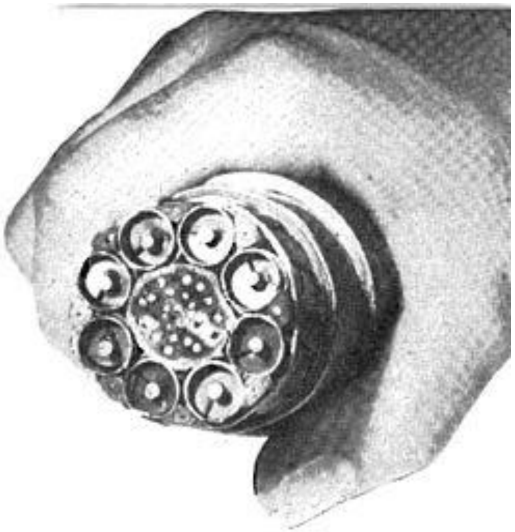


- Cabo Coaxial Banda Larga
  - Cabo duplo - transmissões em cabo são retransmitidas pelo head-end no outro cabo.
  - Cabo simples - Head-end recebe em uma freqüência e retransmite em outra.
  - Banda passante: freqüência fixa entre pares, disputa pelo meio, etc.

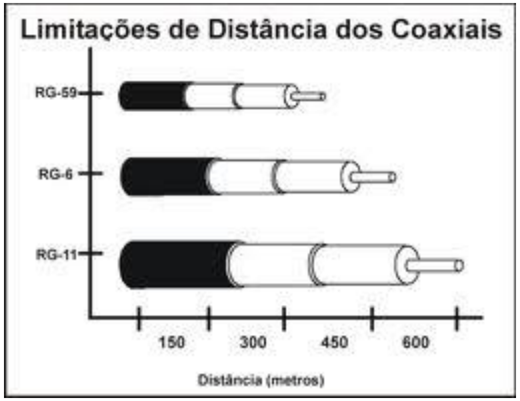
Cabo Coaxial

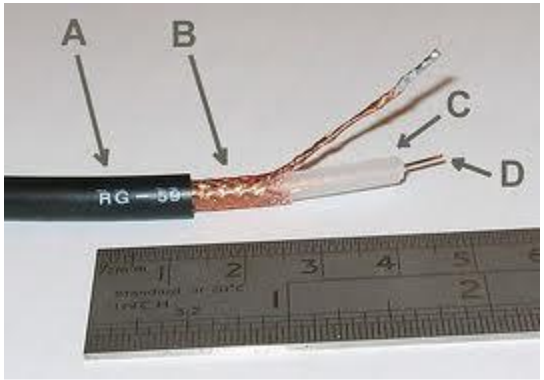






Cabo Coaxial





Power Line

- Uso de instalação elétrica para transmissão de dados – uso de diferentes frequências
- Qualidade sujeita à condições físicas do cabeamento – até 100Mbps

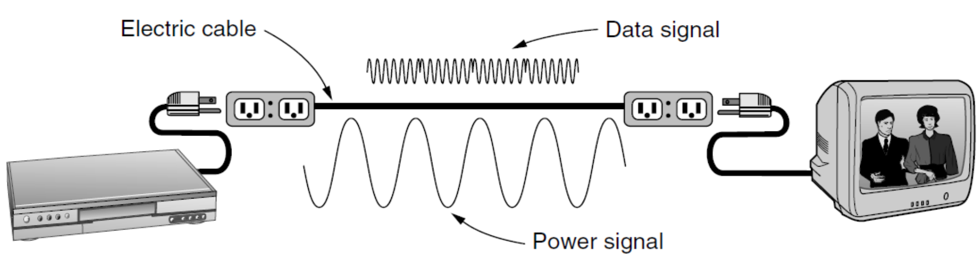


Figure 2-5. A network that uses household electrical wiring.

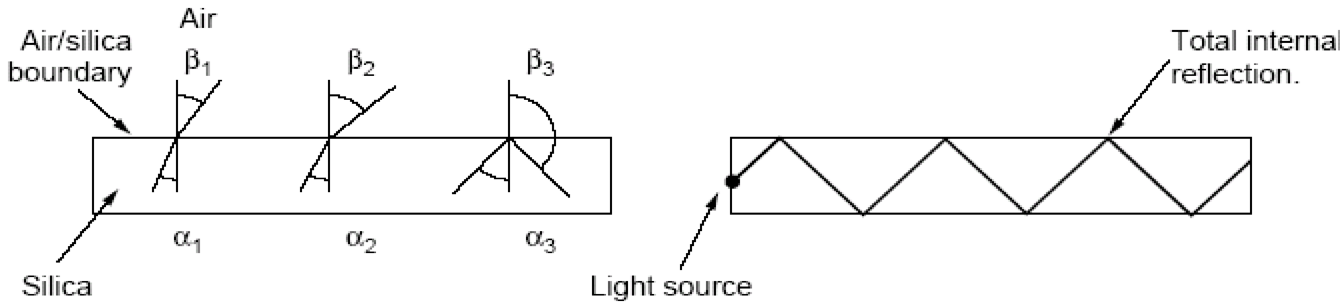
Fibras Ópticas

Fibras Óticas

- Princípio: refração.
- Multimodais e unimodais.
- 400Gbps por 12Km sem necessidade de amplificação

✓ Três componentes: fonte de luz, fibra e detector.

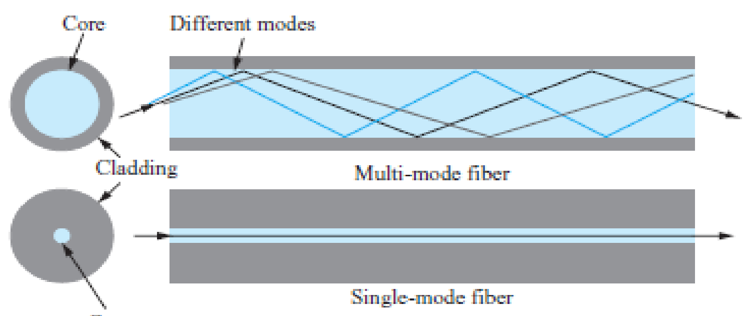
✓ Solitons: pulsos com formato inverso ao seno hiperbólico - grandes distâncias sem distorção.



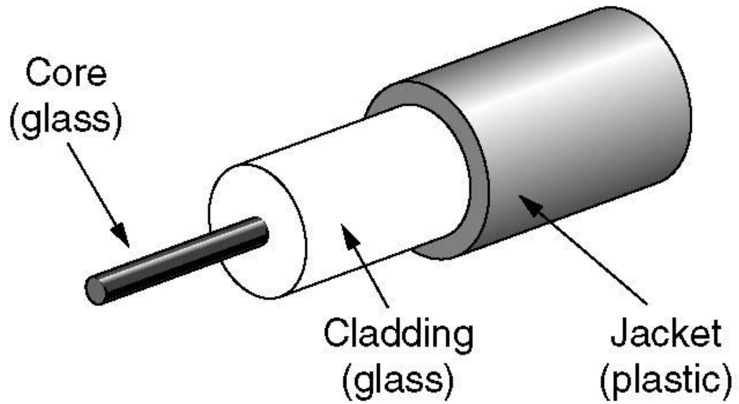
Fibras Ópticas

Fibras Ópticas

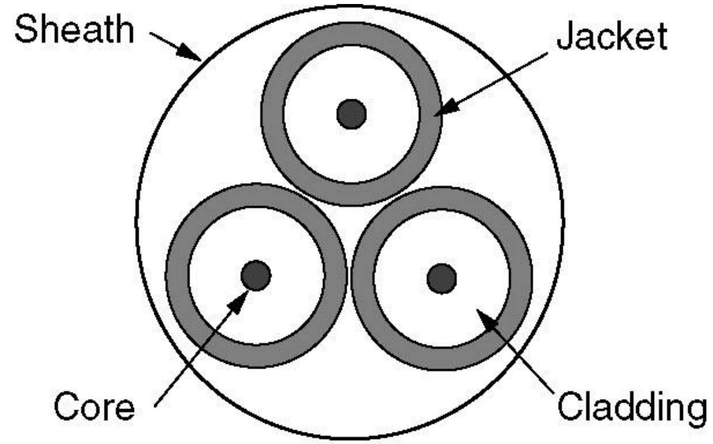
- Fibras Óticas
  - Diâmetro: multimodais (50 micra), unimodais (10 micra).
  - Conexões: conexões (10% a 20% de perda), encaixadores (10% de perda), fusão.
  - Fontes de luz: diodos emissores de luz, lasers e semicondutores.
  - Recepção fotodiodo: 100 Gbps.



Fiber Cables



(a)

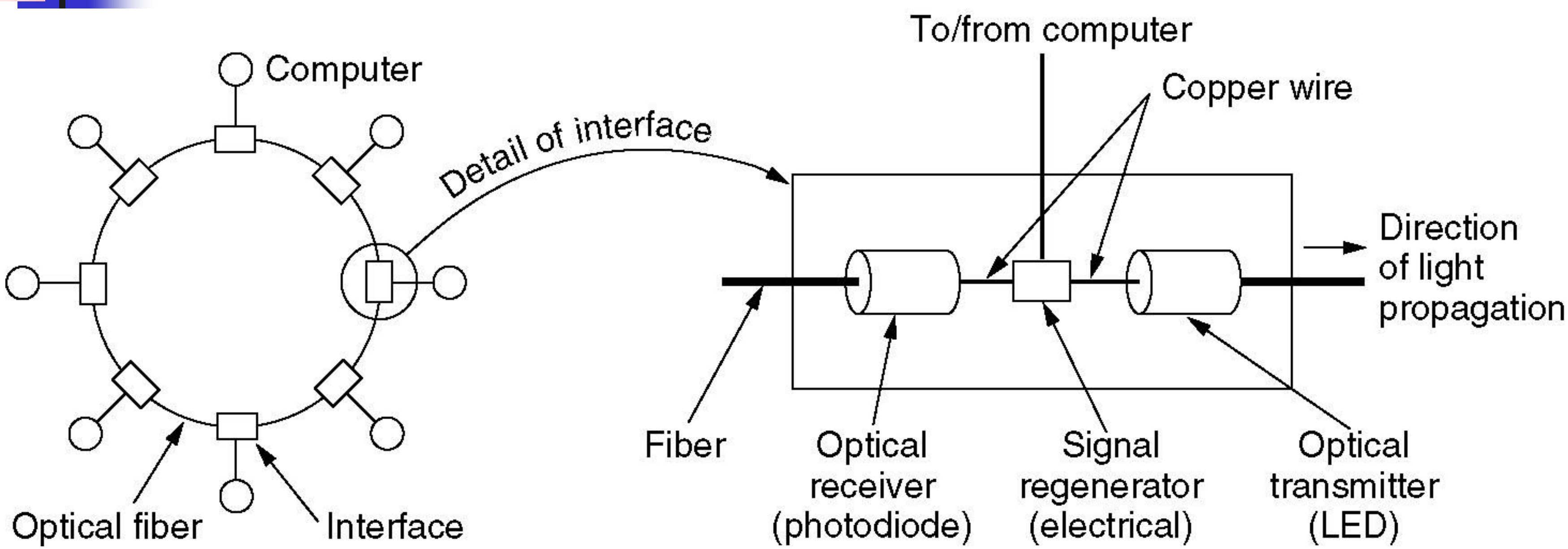


(b)

Fiber Cables (2)

Item	LED	Semiconductor laser
Data rate	Low	High
Fiber type	Multimode	Multimode or single mode
Distance	Short	Long
Lifetime	Long life	Short life
Temperature sensitivity	Minor	Substantial
Cost	Low cost	Expensive

Redes de Fibras Ópticas



Redes Fibras Ópticas

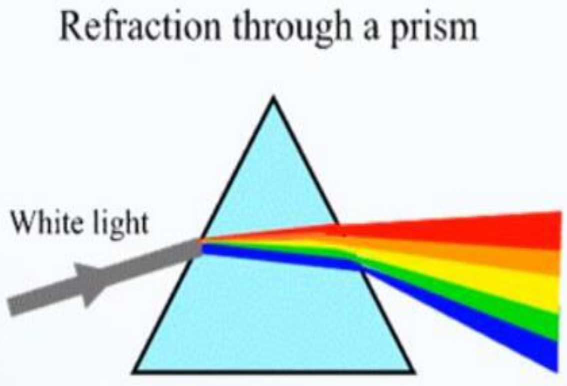
- Fibras Óticas
  - Interface passiva:
    - Conectores fundidos a fibra, diodos emissores de luz e fotodiodos.
    - Em caso de falha na interface passiva, não compromete transmissão
    - Perdem luz nas junções.

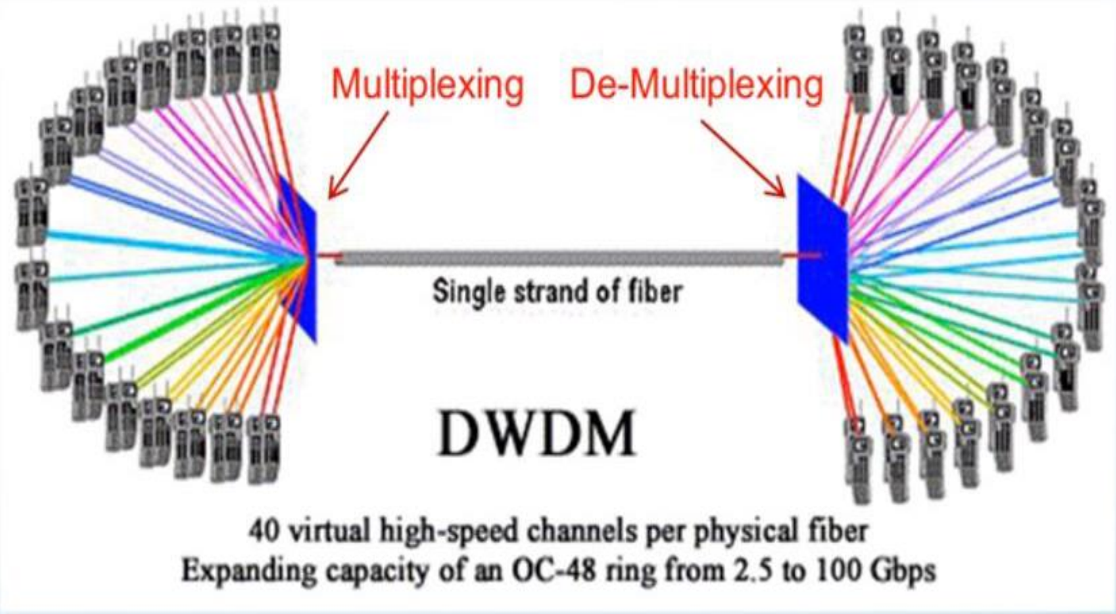
Redes Fibras Ópticas

- Fibras Óticas
  - Repetidor ativo:
    - Converte sinal ótico em elétrico, regenera potência e converte sinal elétrico em ótico
    - Podem operar com altas bandas passantes
    - Em caso de falha, compromete o anel
    - Longas distâncias

What is WDM?

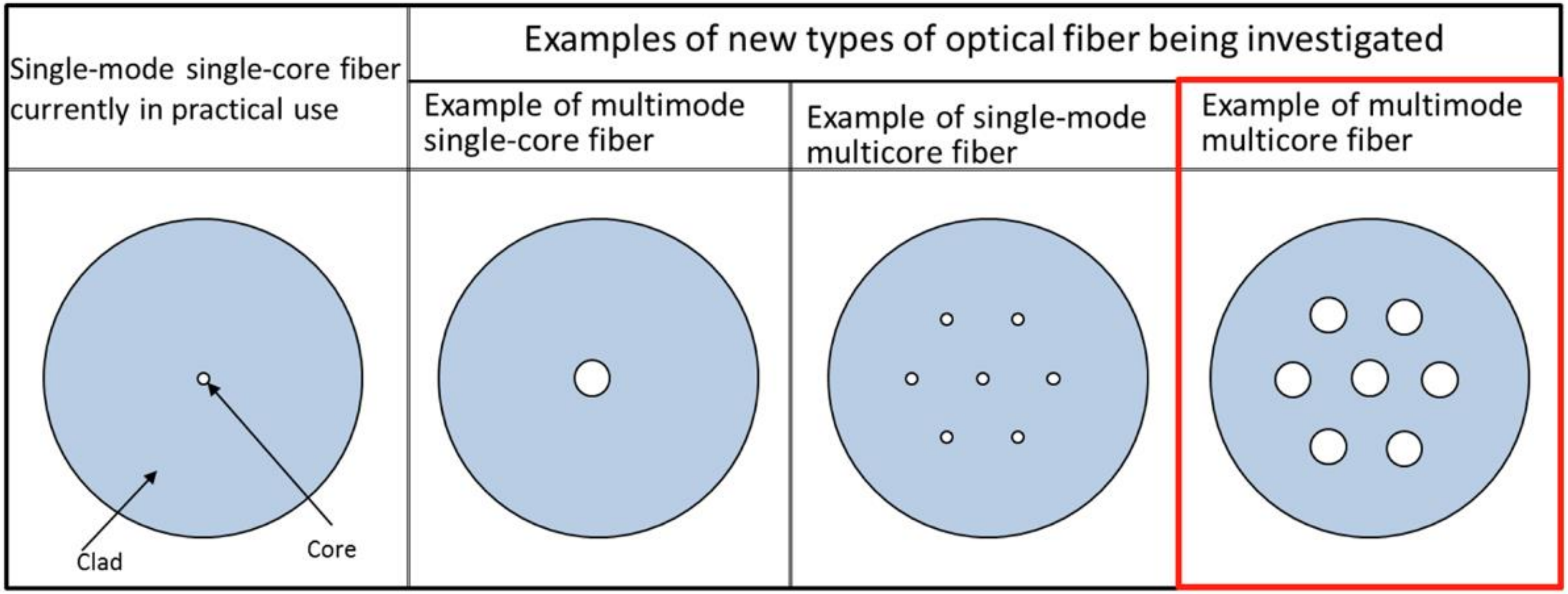
WDM = Wavelength Division Multiplexing



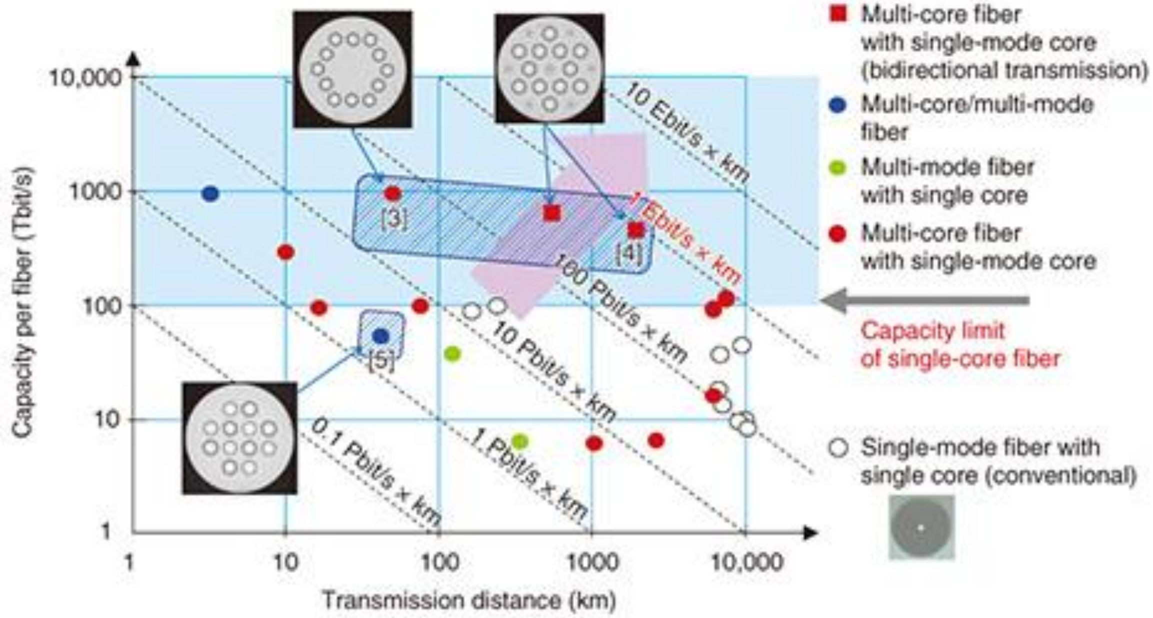


WDM is used on fiber optics to increase the capacity of a single fiber

Multicore Fiber



Multicore Fiber



China Mobile drives 800G 1100 km with Huawei, YOFC

The tests used 800G coherent technology Huawei introduced as a module in February 2020 for its OptiXtrans optical transport platforms.

Author — Stephen Hardy

Apr 6th, 2021

Huawei implanta rede de 400 Gb com Telefónica Chile

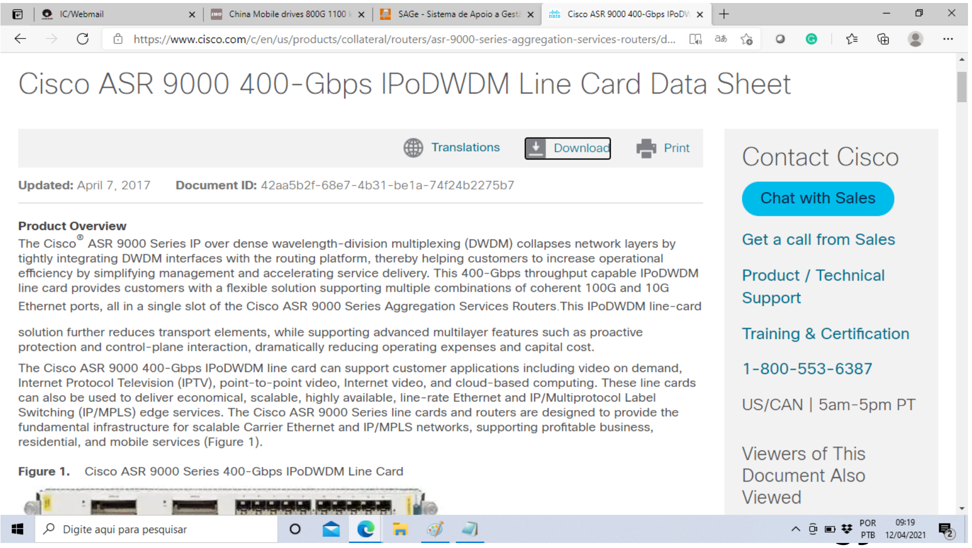
Por Redação - 10/12/13, 17:37 Atualizado em 10/12/13, 17:37

A Huawei anunciou na terça, 10, uma parceria com a Telefónica Chile para a implantação do que alega ser a primeira rede comercial WDM de 400 GB baseada no padrão de rede de transporte ótico (OTN). Segundo a fornecedora chinesa, a infraestrutura será a rede WDM metropolitana mais rápida da indústria. A ideia é que a operadora chilena aumente a largura de banda para serviços como LTE e IPTV na capital Santiago, que tem o maior consumo de banda larga do país.

Notícias relacionadas

RIM registra queda de 47% na receita no acumulado de nove meses

Base de smartphones vai triplicar em cinco anos no mundo, diz pesquisa



Cisco ASR 9000 400-Gbps IPoDWDM Line Card Data Sheet

Updated: April 7, 2017 **Document ID:** 42aa5b2f-68e7-4b31-be1a-74f24b2275b7

Product Overview

The Cisco® ASR 9000 Series IP over dense wavelength-division multiplexing (DWDM) collapses network layers by tightly integrating DWDM interfaces with the routing platform, thereby helping customers to increase operational efficiency by simplifying management and accelerating service delivery. This 400-Gbps throughput capable IPoDWDM line card provides customers with a flexible solution supporting multiple combinations of coherent 100G and 10G Ethernet ports, all in a single slot of the Cisco ASR 9000 Series Aggregation Services Routers This IPoDWDM line-card solution further reduces transport elements, while supporting advanced multilayer features such as proactive protection and control-plane interaction, dramatically reducing operating expenses and capital cost.

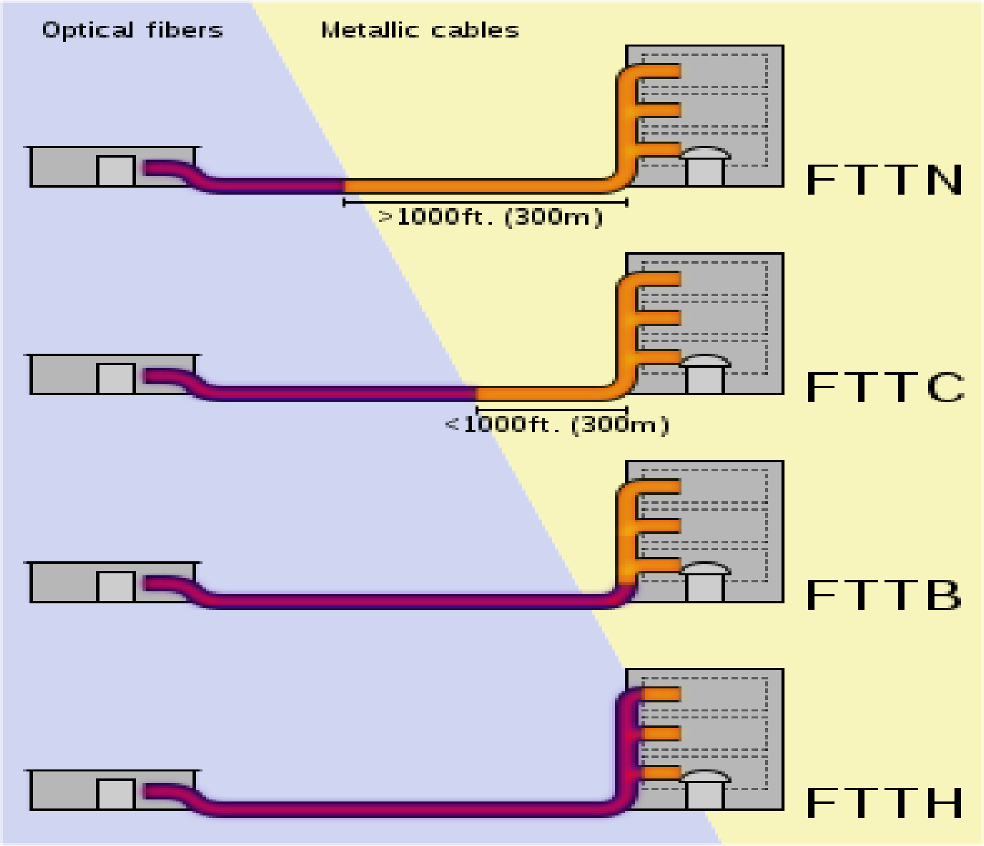
The Cisco ASR 9000 400-Gbps IPoDWDM line card can support customer applications including video on demand, Internet Protocol Television (IPTV), point-to-point video, Internet video, and cloud-based computing. These line cards can also be used to deliver economical, scalable, highly available, line-rate Ethernet and IP/Multiprotocol Label Switching (IP/MPLS) edge services. The Cisco ASR 9000 Series line cards and routers are designed to provide the fundamental infrastructure for scalable Carrier Ethernet and IP/MPLS networks, supporting profitable business, residential, and mobile services (Figure 1).

Figure 1. Cisco ASR 9000 Series 400-Gbps IPoDWDM Line Card

Fiber-to-the-curb Fiber-to-the-home

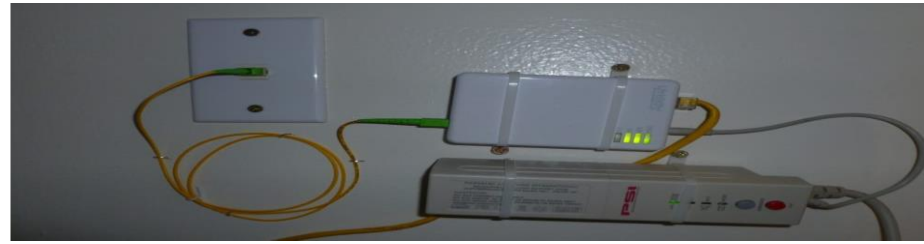
- **FTTH** (*fiber-to-the-home*): Fiber reaches the boundary of the living space, such as a box on the outside wall of a home. Passive optical networks and point-to-point Ethernet are architectures that are capable of delivering triple-play services over FTTH networks directly from an operator's central office
- **TTN / FTTLA** (*fiber-to-the-node, -neighborhood, or -last-amplifier*): Fiber is terminated in a street cabinet, possibly miles away from the customer premises, with the final connections being copper.
- **FTTC / FTTK** (*fiber-to-the-curb/kerb, -closet, or -cabinet*): This is very similar to FTTN, but the street cabinet or pole is closer to the user's premises, typically within 1,000 feet (300 m), within range for high-bandwidth copper technologies

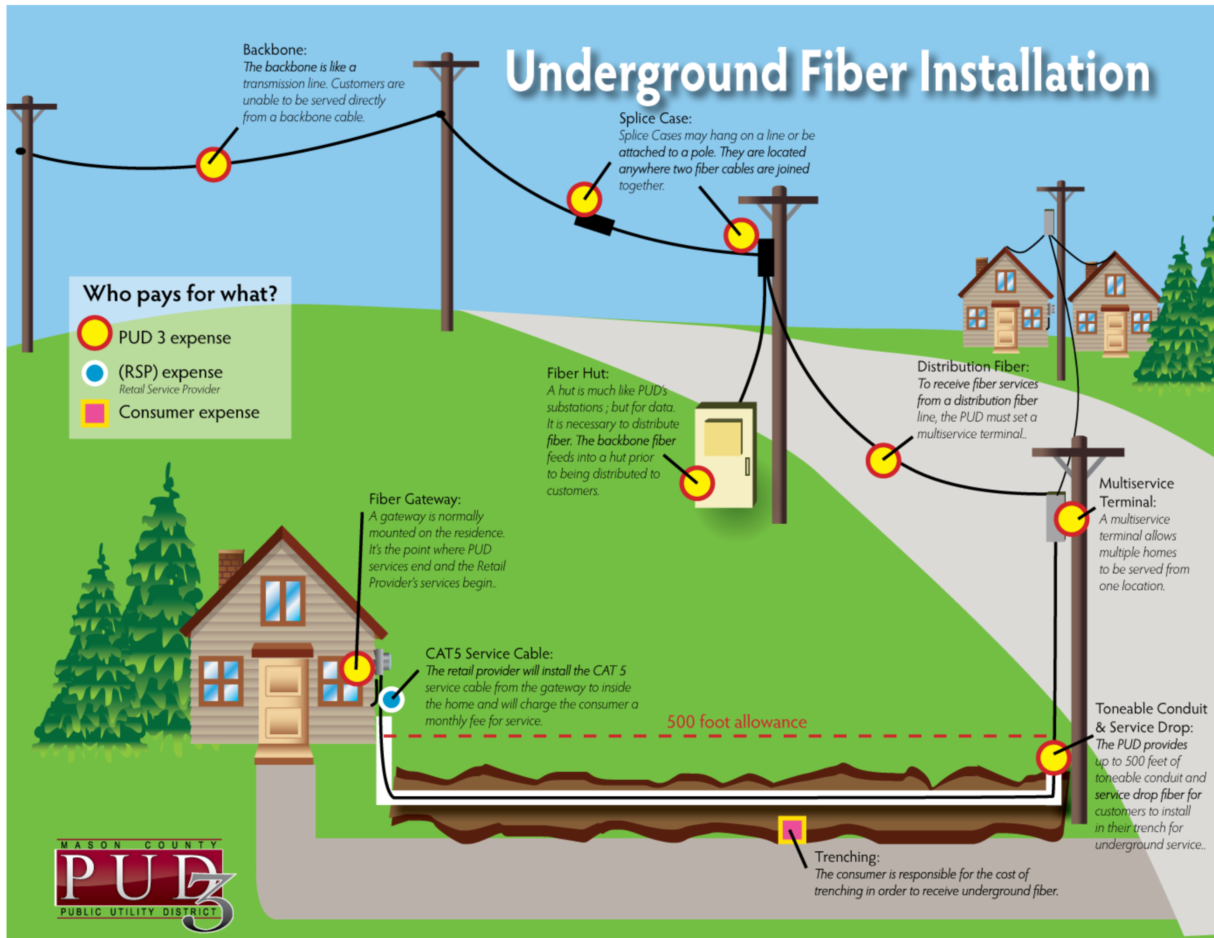
Fiber-to-X



Optical fibers
Metallic cables
FTTN
>1000ft. (300m)
FTTC
<1000ft. (300m)
FTTB
FTTH

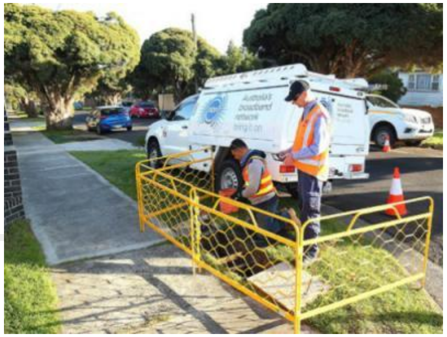
FTTH



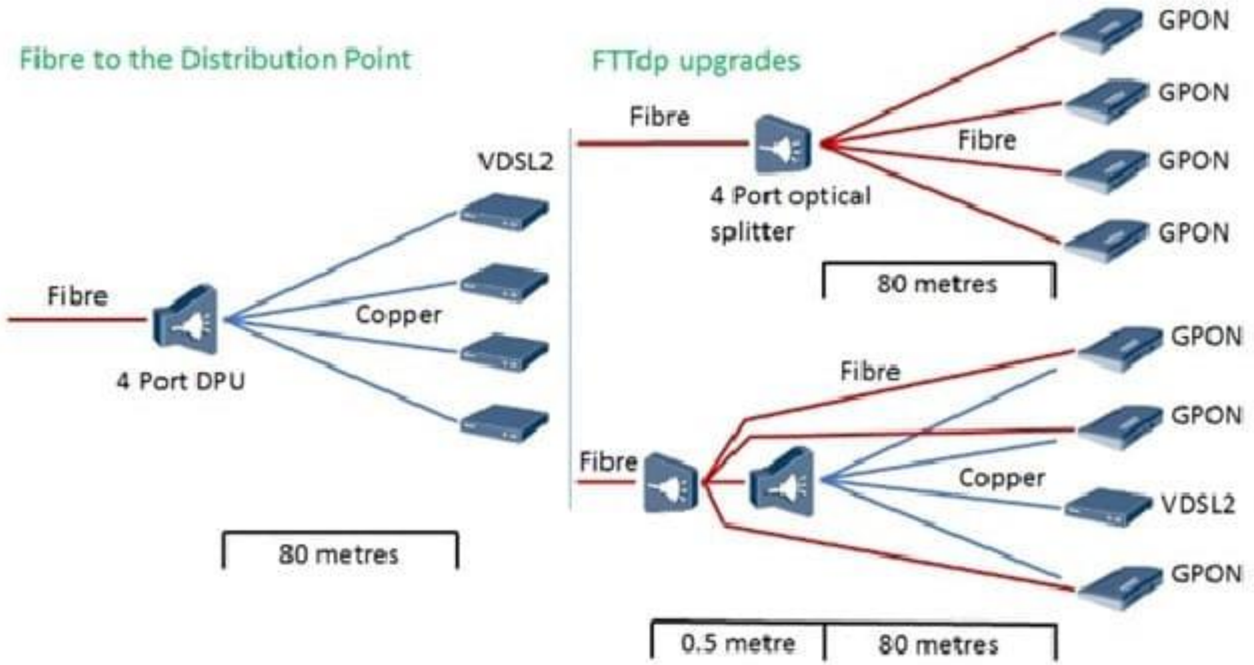


Underground Fiber Installation
Backbone:
The backbone is like a transmission line. Customers are unable to be served directly from a backbone cable.
Splice Case:
Splice Cases may hang on a line or be attached to a pole. They are located anywhere two fiber cables are joined together.
Who pays for what?
PUD 3 expense
(RSP) expense
Retail Service Provider
Consumer expense
Fiber Hut:
A hut is much like PUD's substations ; but for data. It is necessary to distribute fiber. The backbone fiber feeds into a hut prior to being distributed to customers.
Distribution Fiber:
To receive fiber services from a distribution fiber line, the PUD must set a multiservice terminal.
Multiservice Terminal:
A multiservice terminal allows multiple homes to be served from one location.
Fiber Gateway:
A gateway is normally mounted on the residence. It's the point where PUD services end and the Retail Provider's services begin.
CAT5 Service Cable:
The retail provider will install the CAT 5 service cable from the gateway to inside the home and will charge the consumer a monthly fee for service.
500 foot allowance
Toneable Conduit & Service Drop:
The PUD provides up to 500 feet of toneable conduit and service drop fiber for customers to install in their trench for underground service.
Trenching:
The consumer is responsible for the cost of trenching in order to receive underground fiber.
MASON COUNTY
PUD 3
PUBLIC UTILITY DISTRICT

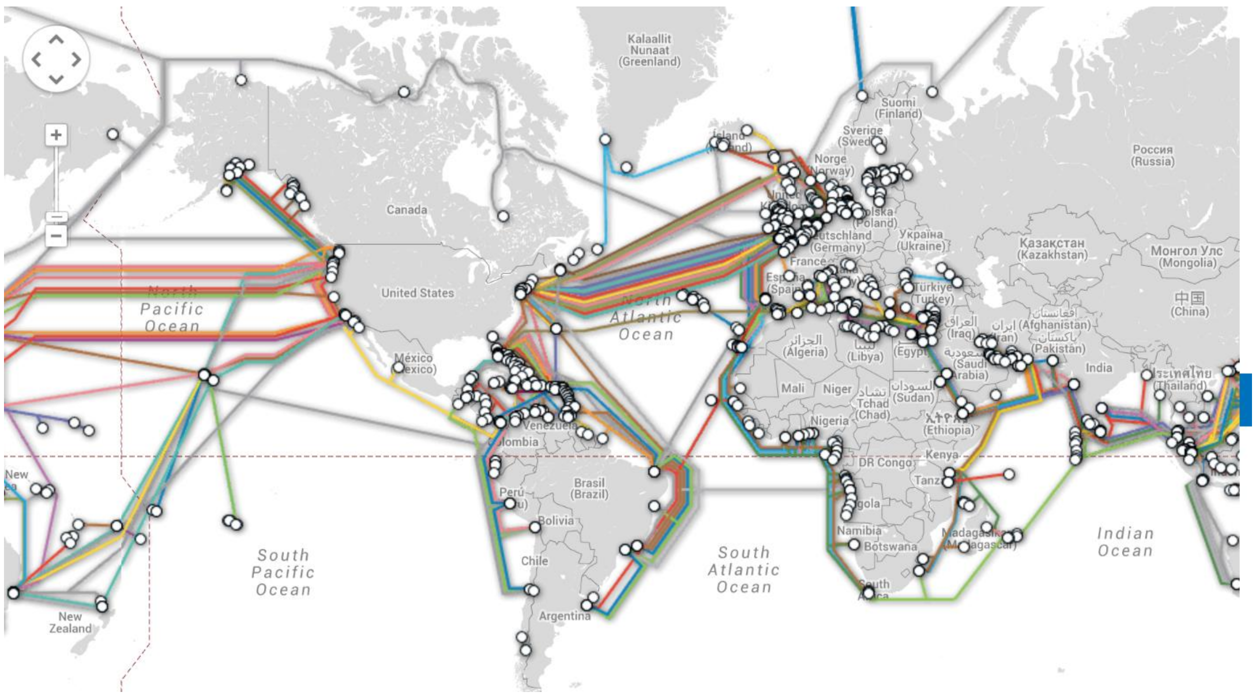
FTTC



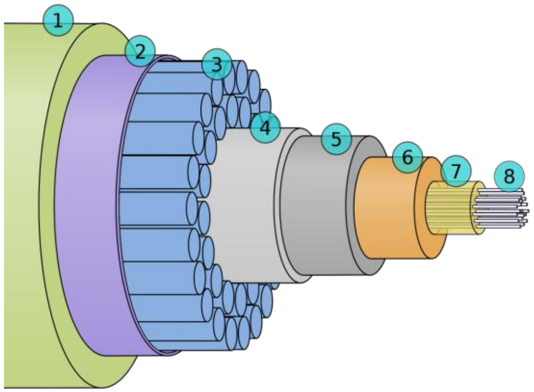

Fibre broadband is here
alamy stock photo

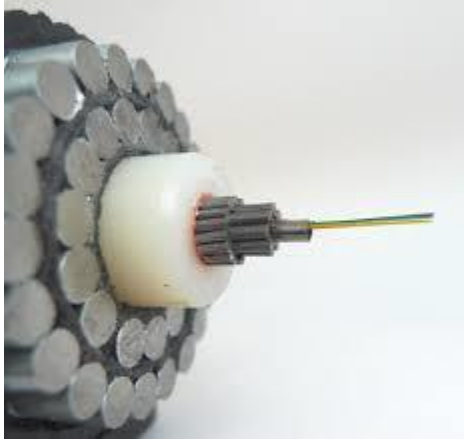

Fibre to the Distribution Point
FTTdp upgrades
Fibre
4 Port DPU
Copper
VDSL2
80 metres
Fibre
4 Port optical splitter
Fibre
GPON
GPON
GPON
GPON
80 metres
Fibre
Fibre
Copper
GPON
GPON
VDSL2
GPON
0.5 metre
80 metres

Interligação Redes Continentais



Interligação Redes Continentais





Fibras Ópticas

Advantages and Disadvantages of Optical Fiber

Advantages Fiber-optic cable has several advantages over metallic cable (twisted-pair or coaxial).

- D Higher bandwidth. Fiber-optic cable can support dramatically higher bandwidths (and hence data rates) than either twisted-pair or coaxial cable. Currently, data rates and bandwidth utilization over fiber-optic cable are limited not by the medium but by the signal generation and reception technology available.
- D Less signal attenuation. Fiber-optic transmission distance is significantly greater than that of other guided media. A signal can run for 50 km without requiring regeneration. We need repeaters every 5 km for coaxial or twisted-pair cable.
- D Immunity to electromagnetic interference. Electromagnetic noise cannot affect fiber-optic cables.
- O Resistance to corrosive materials. Glass is more resistant to corrosive materials than copper.
- O Light weight. Fiber-optic cables are much lighter than copper cables.
- O Greater immunity to tapping. Fiber-optic cables are more immune to tapping than copper cables. Copper cables create antenna effects that can easily be tapped.

Fibras Ópticas

Disadvantages There are some disadvantages in the use of optical fiber.

- Installation and maintenance. Fiber-optic cable is a relatively new technology. Its installation and maintenance require expertise that is not yet available everywhere.
- Unidirectional light propagation. Propagation of light is unidirectional. If we need bidirectional communication, two fibers are needed.
- Cost. The cable and the interfaces are relatively more expensive than those of other guided media. If the demand for bandwidth is not high, often the use of optical fiber cannot be justified.

Fibras Ópticas

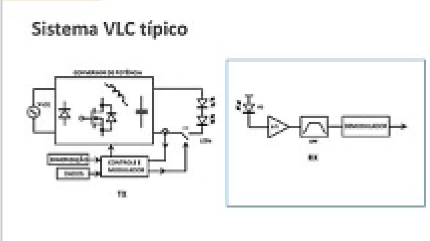
- Desvantagens Fibras:
  - Engenharia não muito disseminada.
  - Interfaces caras.
  - Comunicação unidirecional.

LIFI

Detalhes da tecnologia

Os diodos emissores de luz (LED's) podem ser ligados e desligados mais rápido do que o olho humano pode detectar já que a velocidade de operação dos LED's é menor do que 1 μs, gerando, consequentemente, a aparência de continuidade da fonte de luz. Esse processo de ligamento e desligamento invisível ao olho humano permite a transmissão de dados usando códigos binários, onde o LED ligado corresponde ao binário '1', e o desligado ao binário '0'. Assim, é possível codificar os dados por meio da variação da frequência da luz. Após esse processo, um dispositivo sensível à luz (fotossensor) recebe o sinal e o converte de volta para o formato original do dado.

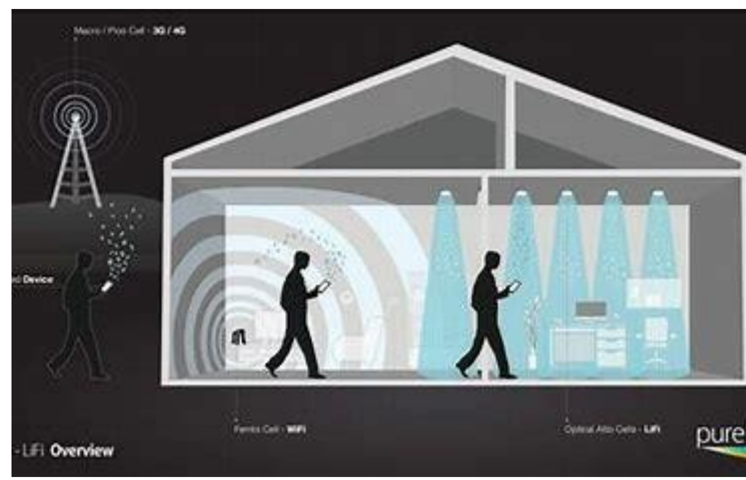
Esse método de utilizar pulsos rápidos de luz para transmitir informação é tecnicamente referenciado como Comunicação por Luz Visível (CLV), onde o mesmo utiliza luz visível entre 400 e 800 terahertz. Dados que excedem 100 Mbps podem ser alcançados através de LED's de alta velocidade com multiplexação adequada. Paralelamente, a transmissão de dados usando conjuntos de LED's, onde cada LED transmite um único fluxo de dados, também pode ser usado para incrementar a frequência de dados pelo CLV.



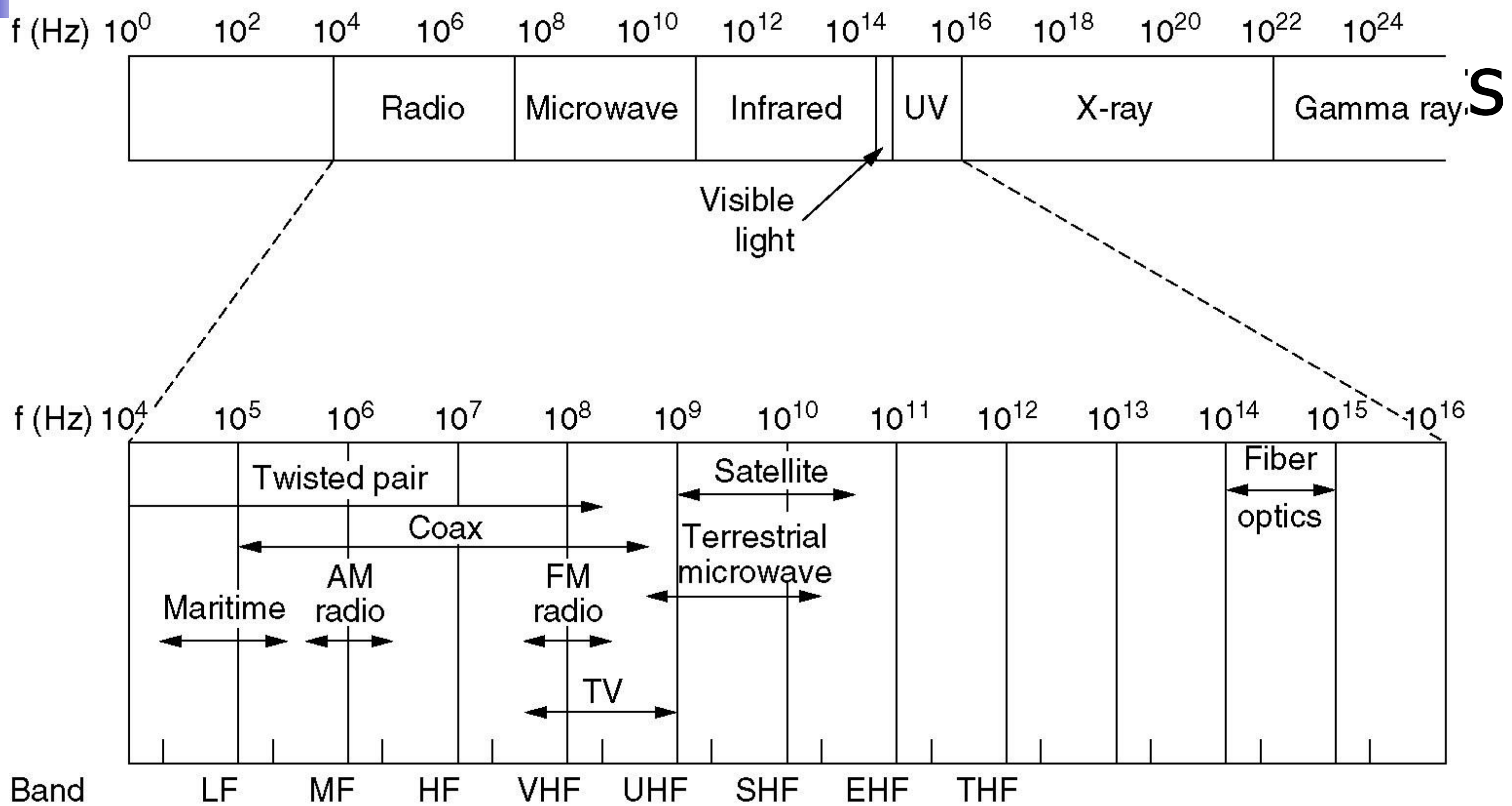
Sistema de Comunicação por Luz Visível padrão.

Padronização

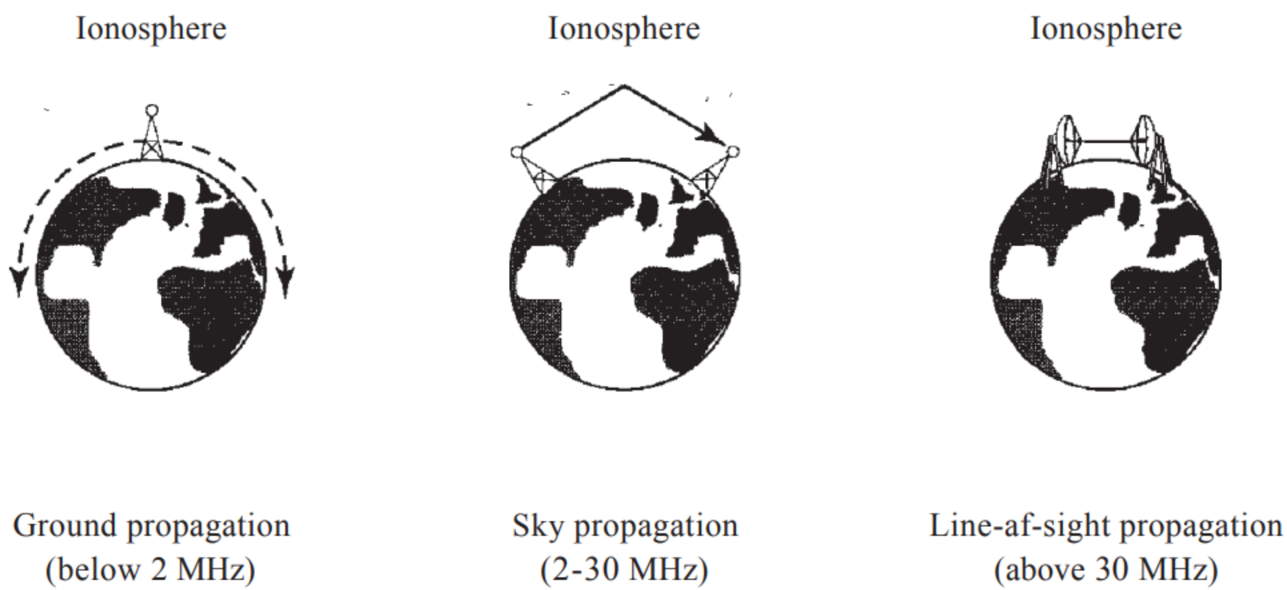
LIFI



Spectrum Eletromagnético



Transmissão



Rádio

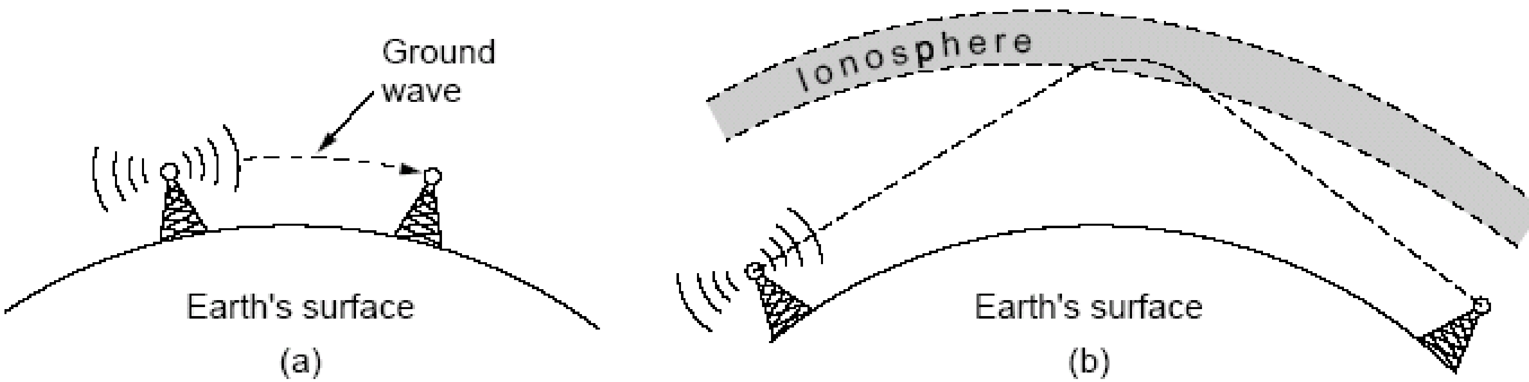
Rádio

- Onidirecional: transmissor e receptor não precisam estar alinhados.
- Baixas freqüências atravessam prédios.

✓ Altas freqüências tendem a viajar em linha reta e ricochetear, interferência.

✓ AM utiliza faixa MF, 1000 Km raio.

✓ HF, VHF - ondas são ricocheteadas na ionosfera.



Spectrum Eletromagnético

Band	*Range*	*Propagation*	*Application*
VLF (very low frequency)	3-30 kHz	Ground	Long-range radio navigation
LF (low frequency)	30-300 kHz	Ground	Radio beacons and navigational locators
MF (middle frequency)	300 kHz-3 MHz	Sky	AM radio
HF (high frequency)	3-30 MHz	Sky	Citizens band (CB), shipiaircraft communication
VHF (very high frequency)	30-300 MHz	Sky and line-of-sight	VHF TV, FM radio
UHF (ultrahigh frequency)	300 MHz-3 GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
SHF (superhigh frequency)	3-30 GHz	Line-of-sight	Satellite communication
EHF (extremely high frequency)	30-300 GHz	Line-of-sight	Radar, satellite

Spectrum Eletromagnético

- Espectro Eletromagnético
  - Velocidade no ar 3×10^8 m/s (2/3 no cabo)
  - $\lambda f = c$
  - majora transmissões, banda estreita
  - spread spectrum - transmissão muda de frequência

Hedy Lamarr

Banda industrial/científica/médica

- não necessita permissão, tipicamente 902 a 928 MHz 5.725 a 5.850 GHz

Banda industrial/científica/médica

- IEEE 802.11/Wi-Fi 2450 MHz e 5800 MHz bands
- Bluetooth 2450 MHz band : WPAN
- IEEE 802.15.4, ZigBee usa 915 MHz and 2450 MHz ISM bands.

Banda industrial/científica/médica

Banda industrial/científica/médica

Frequency range		Center frequency	Bandwidth	Type	Availability	Licensed users
6.765 MHz	6.795 MHz	6.78 MHz	30 kHz	A	Subject to local acceptance	FIXED SERVICE & Mobile service
13.553 MHz	13.567 MHz	13.56 MHz	14 kHz	B	Worldwide	FIXED & Mobile services except Aeronautical mobile (R) service
26.957 MHz	27.283 MHz	27.12 MHz	326 kHz	B	Worldwide	FIXED & MOBILE SERVICE except Aeronautical mobile service, CB Radio
40.66 MHz	40.7 MHz	40.68 MHz	40 kHz	B	Worldwide	Fixed, Mobile services & Earth exploration-satellite service
433.05 MHz	434.79 MHz	433.92 MHz	1.74 MHz	A	only in Region 1, subject to local acceptance	AMATEUR SERVICE & RADIOLOCATION SERVICE, additional apply the provisions of footnote 5.280. For Australia see footnote AU.
868.00 MHz	868.90 MHz	868.40 MHz	0.9 MHz	A	Region 1, subject to local acceptance	SHORT-RANGE DEVICES[3]
902 MHz	928 MHz	915 MHz	26 MHz	B	Region 2 only (with some exceptions)	SHORT-RANGE DEVICES, FIXED, Mobile except aeronautical mobile & Radiolocation service; in Region 2 additional Amateur service
2.4 GHz	2.5 GHz	2.45 GHz	100 MHz	B	Worldwide	FIXED, MOBILE, RADIOLOCATION, Amateur & Amateur-satellite service
5.725 GHz	5.875 GHz	5.8 GHz	150 MHz	B	Worldwide	FIXED-SATELLITE, RADIOLOCATION, MOBILE, Amateur & Amateur-satellite service
24 GHz	24.25 GHz	24.125 GHz	250 MHz	B	Worldwide	AMATEUR, AMATEUR-SATELLITE, RADIOLOCATION & Earth exploration-satellite service (active)
61 GHz	61.5 GHz	61.25 GHz	500 MHz	A	Subject to local acceptance	FIXED, INTER-SATELLITE, MOBILE & RADIOLOCATION SERVICE
122 GHz	123 GHz	122.5 GHz	1 GHz	A	Subject to local acceptance	EARTH EXPLORATION-SATELLITE (passive), FIXED, INTER-SATELLITE, MOBILE, SPACE RESEARCH (passive) & Amateur service
244 GHz	246 GHz	245 GHz	2 GHz	A	Subject to local acceptance	RADIOLOCATION, RADIO ASTRONOMY, Amateur & Amateur-satellite service

Type A (footnote 5.138) = frequency bands are designated for *ISM applications*. The use of these frequency bands for ISM applications shall be subject to special authorization by the administration concerned, in agreement with other administrations whose radiocommunication services might be affected. In applying this provision, administrations shall have due regard to the latest relevant ITU-R

Microondas

- Microondas
  - Acima de 100 MHz ondas propagam em linha reta.
  - Alinhamento de transmissor e receptor.
  - Torres mais altas, maior distância necessita repetidores. Torres 100 m, repetidores a cada 80 Km.
  - Fading por múltiplos caminhos, ondas refratadas nas camada baixas da atmosfera.

Microondas

- Microondas
  - Alta freqüência (10 GHz): absorção pela chuva.
  - Dispensa direito de uso do caminho.
  - Baixo custos.

Satélites

- "Grande refletor no espaço"
- Possui transponders que recebem sinais em uma certa faixa de frequência, amplificam e retransmitem em outra faixa de frequência para evitar interferência com o sinal recebido (bent pipe)
- Pode haver processamento digital e data streams retransmitidos em largas faixas de frequência

Satélites

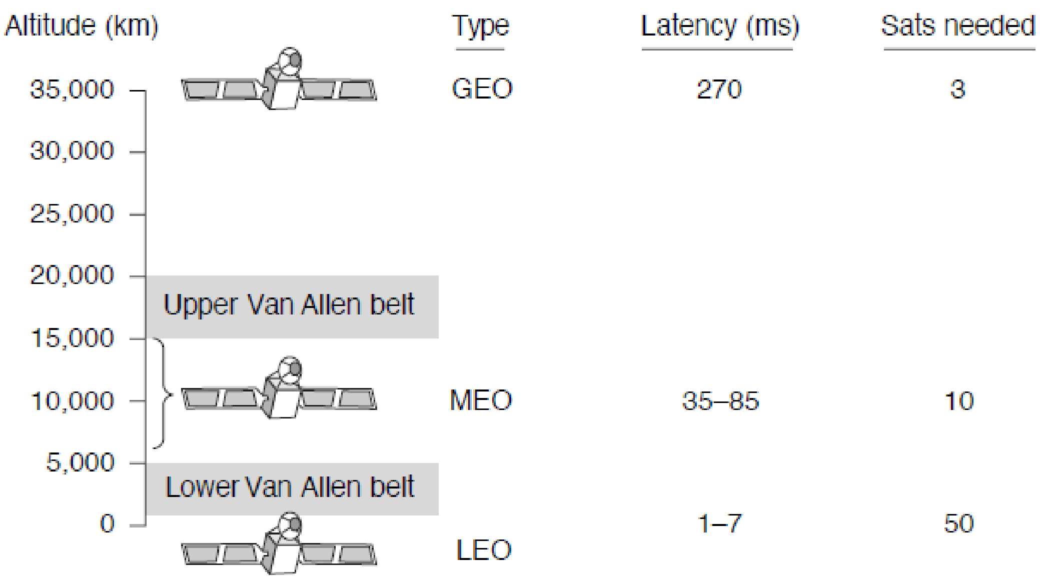


Figure 2-48. Communication satellites and some of their properties, including altitude above the earth, round-trip delay time, and number of satellites needed for global coverage.

Satélites

Band	Downlink	Uplink	Bandwidth	Problems
L	1.5 GHz	1.6 GHz	15 MHz	Low bandwidth; crowded
S	1.9 GHz	2.2 GHz	70 MHz	Low bandwidth; crowded
C	4.0 GHz	6.0 GHz	500 MHz	Terrestrial interference
Ku	11 GHz	14 GHz	500 MHz	Rain
Ka	20 GHz	30 GHz	3500 MHz	Rain, equipment cost

Figure 2-49. The principal satellite bands.

- Satélites geoestáticos, altura 36 Km, atraso de 270 ms, espaçado de 2 graus, 5000 Kg e 15 a 20 anos de vida útil
- Faixas de frequência alocadas para evitar interferência com transmissões microondas

VSAT

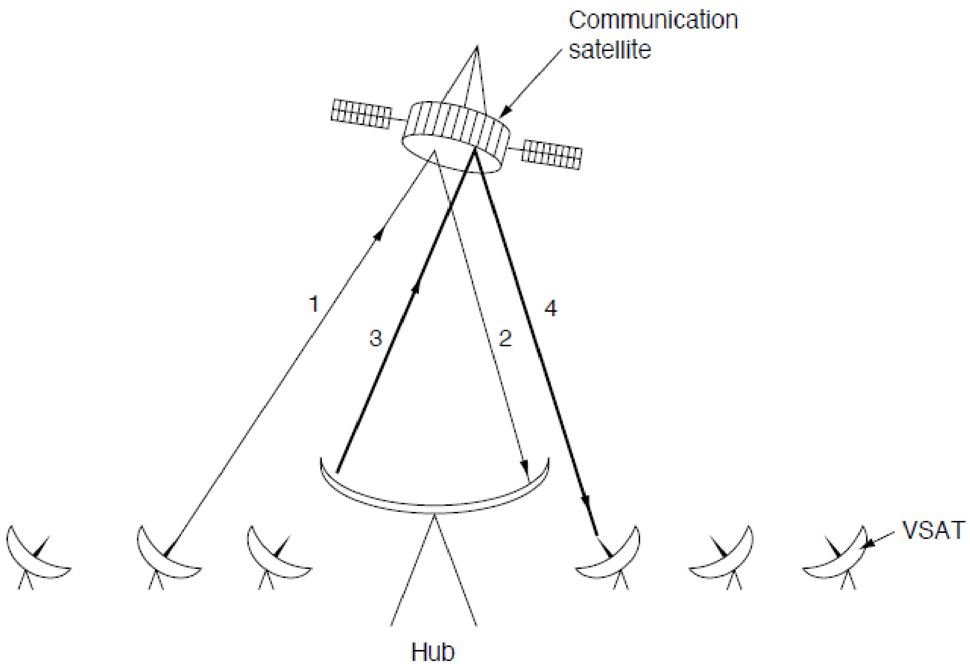


Figure 2-50. VSATs using a hub.

Satélites

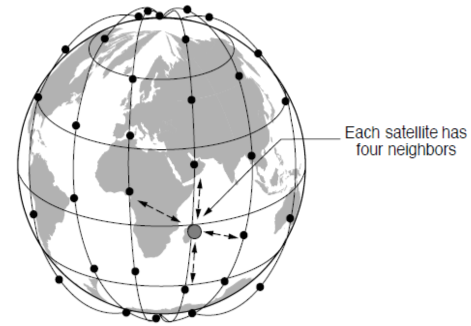
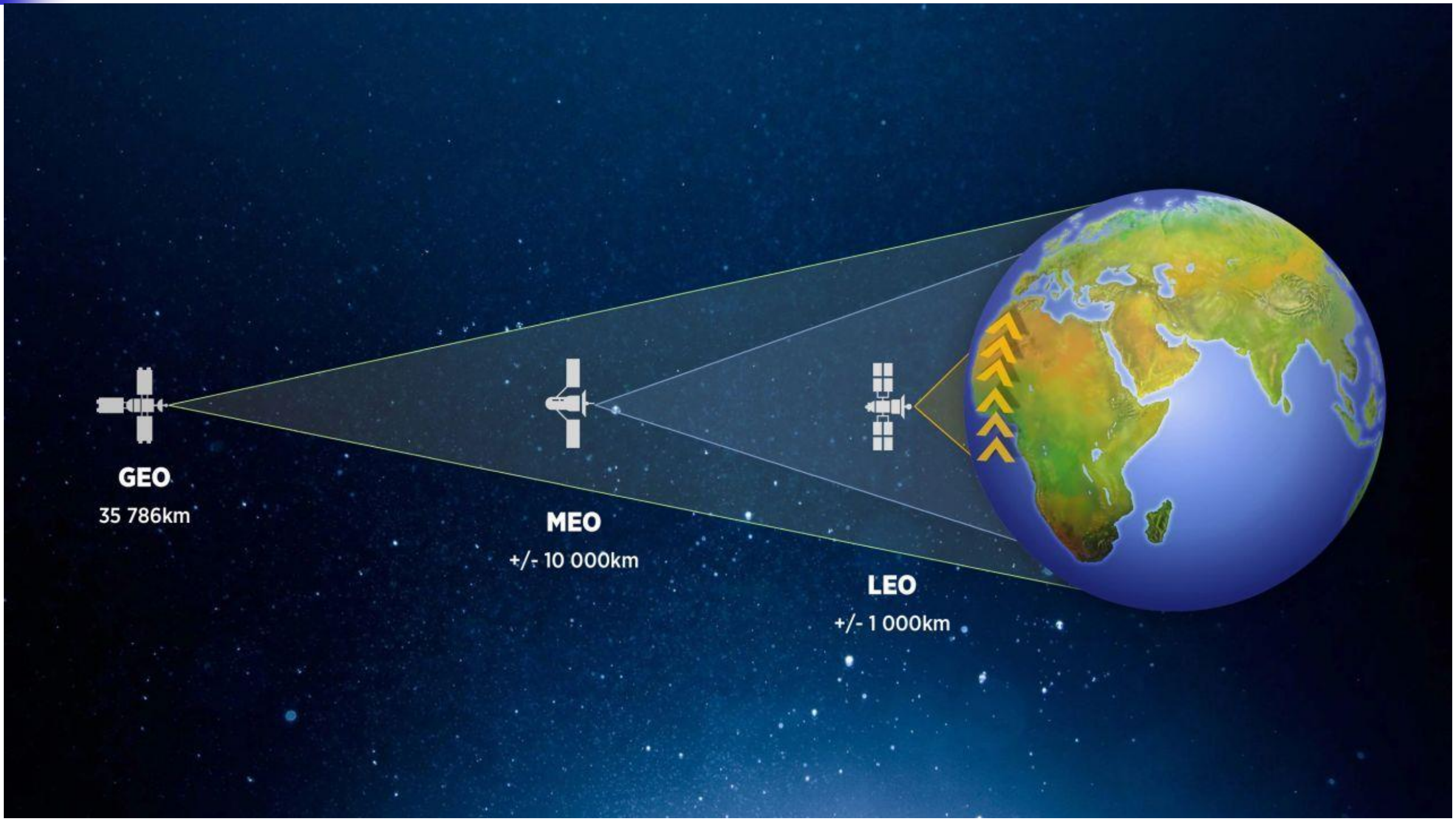


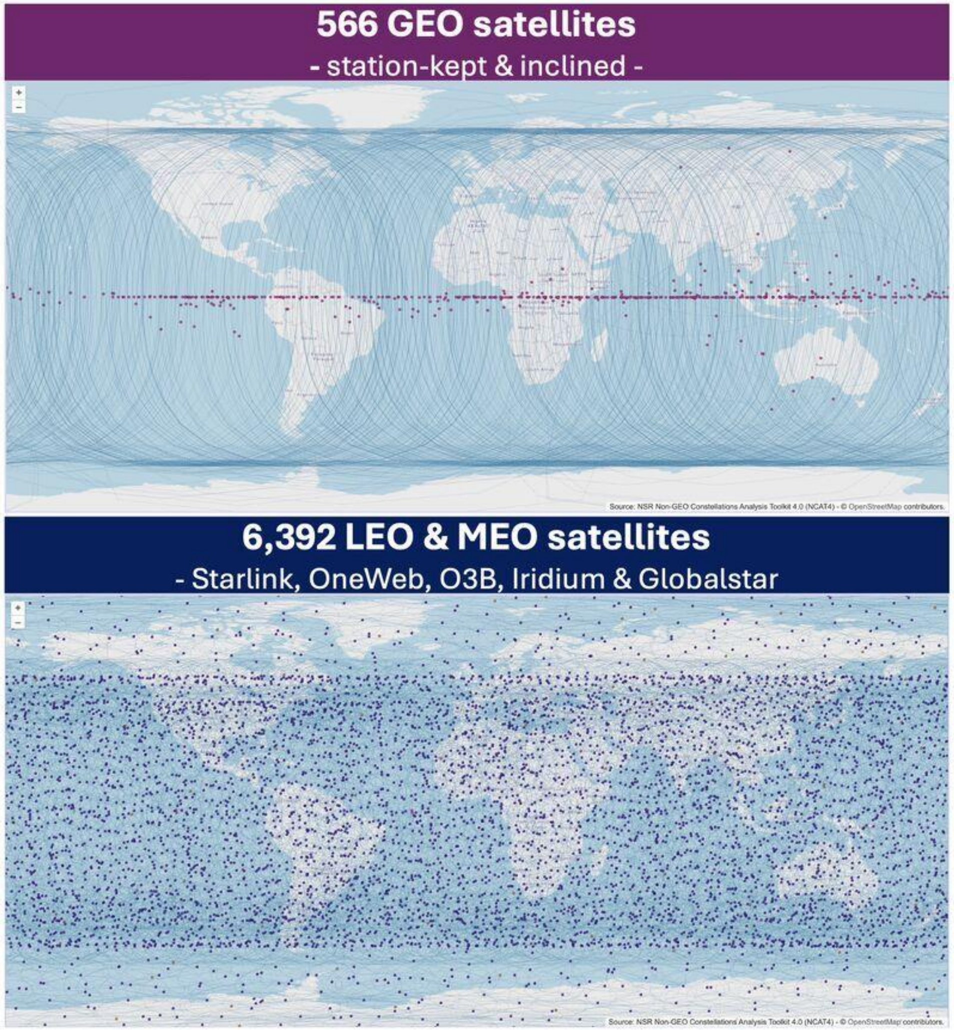
Figure 2-51. The Iridium satellites form six necklaces around the earth.

- Medium-Earth Orbit Satellite (MEOS) – período de 6 horas. 30 GPS satélites a altura de 10.4 Km altura, 7 a 10 anos
- Low-Earth orbit Sattelie (LEOS) – altura 0.5 a 1.5 Km, período de 1 ½ a 2 horas, 40 a 150 milissegundos de atraso
- Highly Elliptical Orbit - órbita elíptica, altura e 1 a 39 km, período 12 horas
  - Iridium
  - Globalstar – 48 satletites
  - Cubesat - 10cm3, US 40K

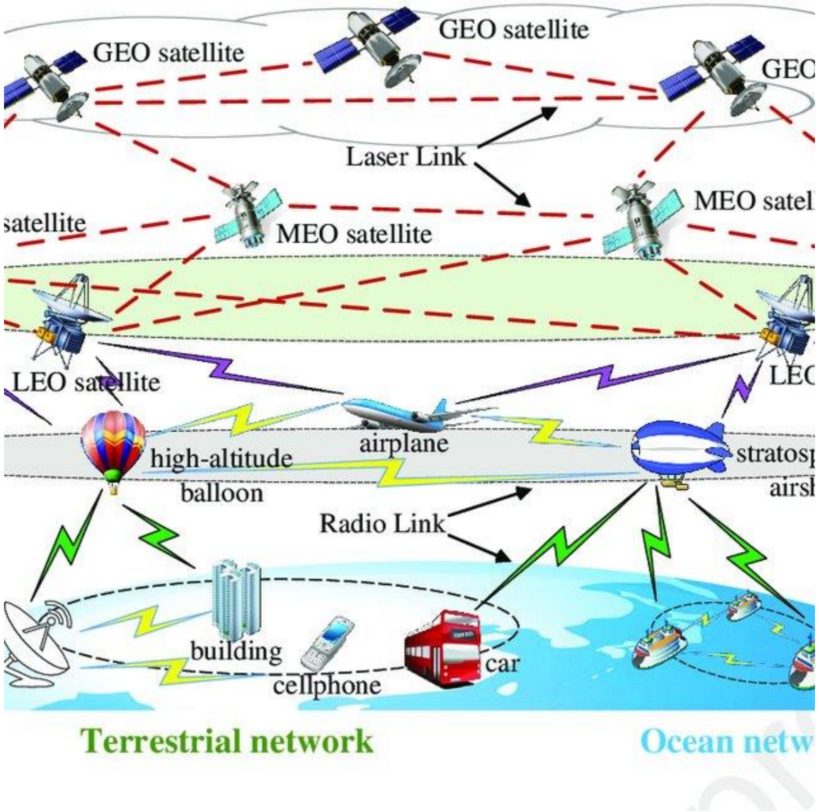
Satélites



Satélites


566 GEO satellites
- station-kept & inclined -
Source: NSR Non-GEO Constellations Analysis Toolkit 4.0 (NCAT4) - © OpenStreetMap contributors.
6,392 LEO & MEO satellites
- Starlink, OneWeb, O3B, Iridium & Globalstar
Source: NSR Non-GEO Constellations Analysis Toolkit 4.0 (NCAT4) - © OpenStreetMap contributors.

Satélites



GEO satellite
GEO satellite
GEO
Laser Link
MEO satellite
MEO satel
satellite
LEO satellite
LEO
high-altitude balloon
airplane
stratosp
airsh
Radio Link
building
cellphone
car
Terrestrial network
Ocean netw

Unmanned Aerial Vehicles (UAVs)

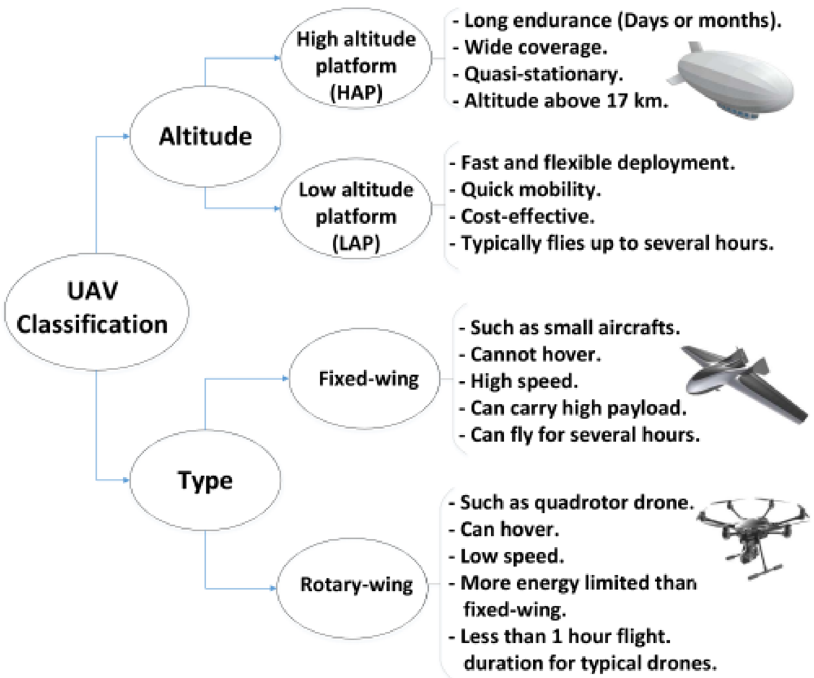
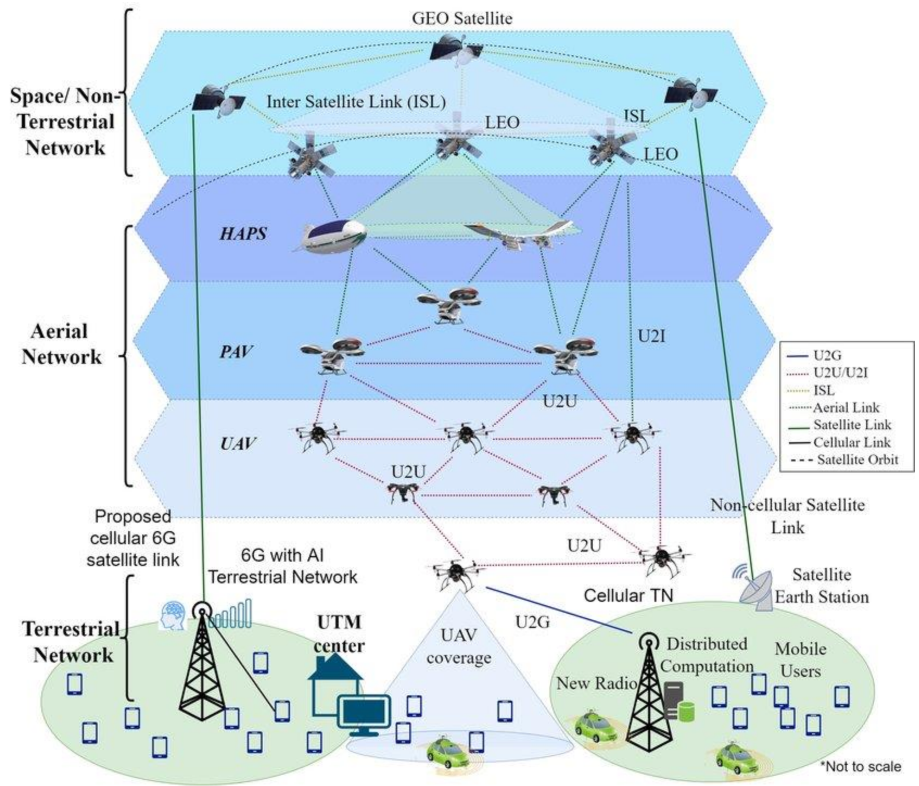


Fig. 1. UAV Classification.

6G Aerial-Terrestrial-Maritime Network



Pe Roberto Landell de Moura