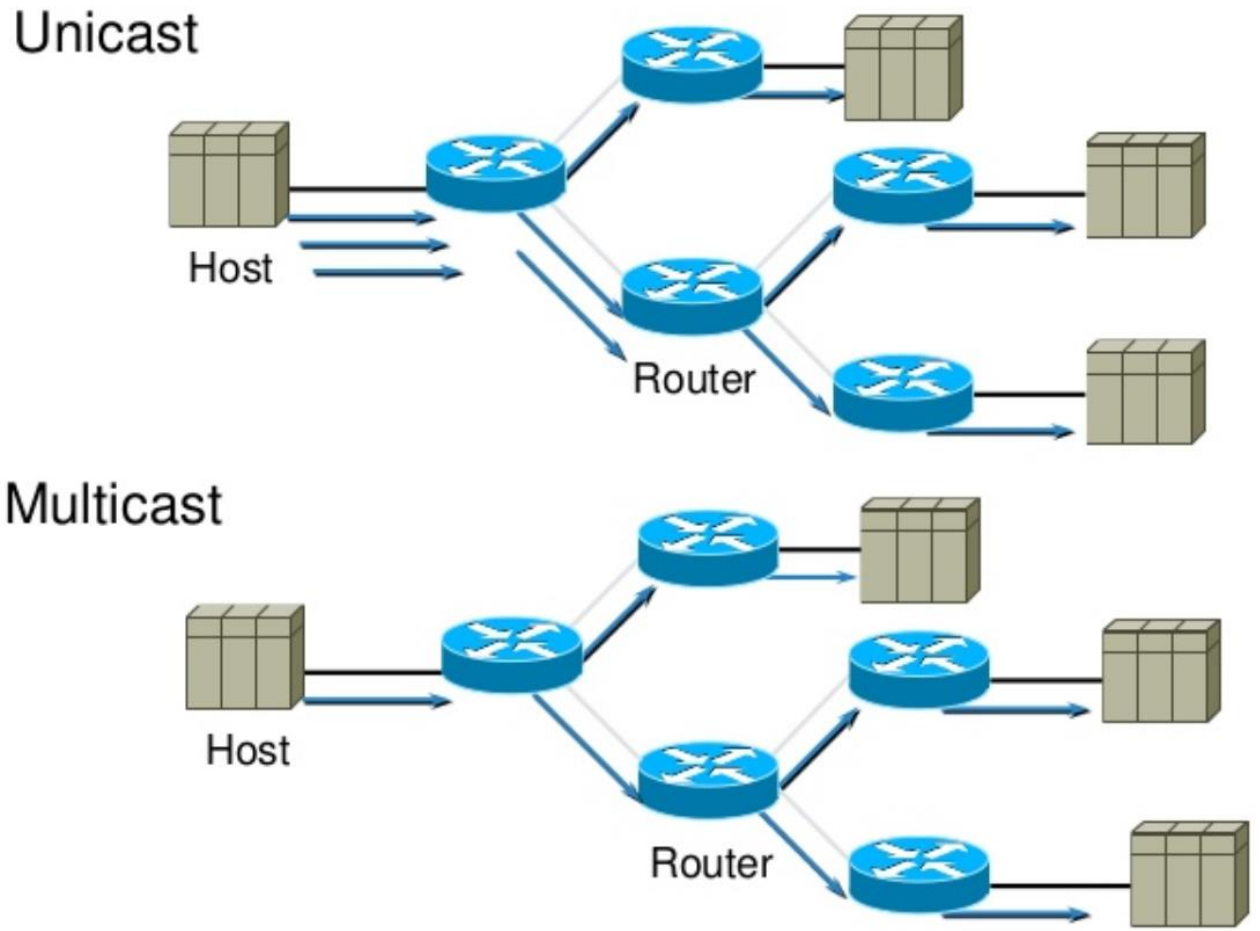
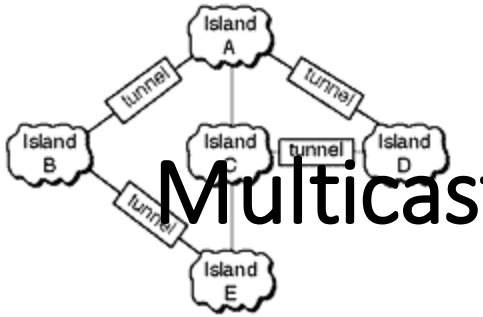
# Distance Vector Multicast Routing Protocol (DVMRP)

- Multicast routing protocol, **RFC1075** (1988).
- Used in first internet multicast backbone (**MBONE**, 1992).
- IPv4 address types: unicast, broadcast, **multicast**.
- **Not connection-oriented**, best-effort delivery (IP).
- Not guarenteed to reach all group members.
- Hosts are **free to join or leave** a group at any time.
- Sender need to be aware of group members.
- Multicast **conserves bandwidth** by forcing network to do packet replication.

- Radio / VIdeo broadcasts, Video conferencing, Distance learning
- Shared applications, Multiplayer gaming, Chat rooms
- Advertisements, Stocks, Distributed databases



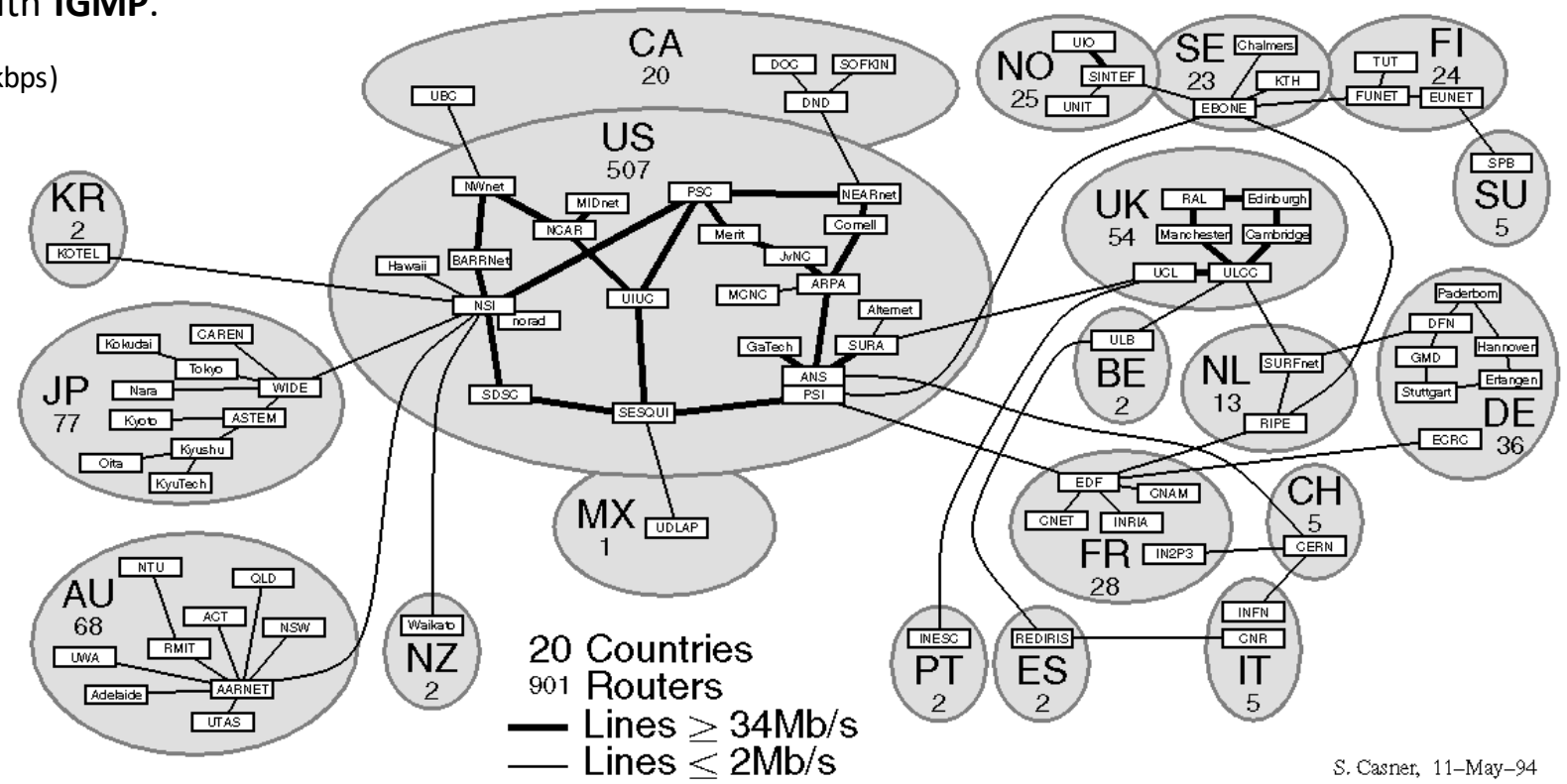



# Multicast Backbone (MBONE)


- Interconnected subnetworks and **multicast routers**.
- Created by Jacobson, Deering, Casner (1992).
- Uses **tunnels** for connecting through unicast routers.
- Uses **DVMRP**, MOSPF for routing along with **IGMP**.
- IP Address: 224.2.0.0 (audio 64kbps, video 120 kbps)

- IETF meetings, US House & Senate sessions
- NASA Space shuttle missions, Satellite weather photos
- **1992**: 40 subnets in 4 countries
- **1993**: Live band performance by Severe Tire Damage
- **1995**: M-bone links in Russia, Antarctica
- **1996**: 2800 subnets in 25 countries
- **2008**: Virtual video conferencing system in use

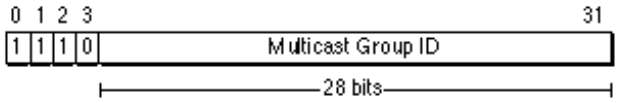
## Major MBONE Routers and Links

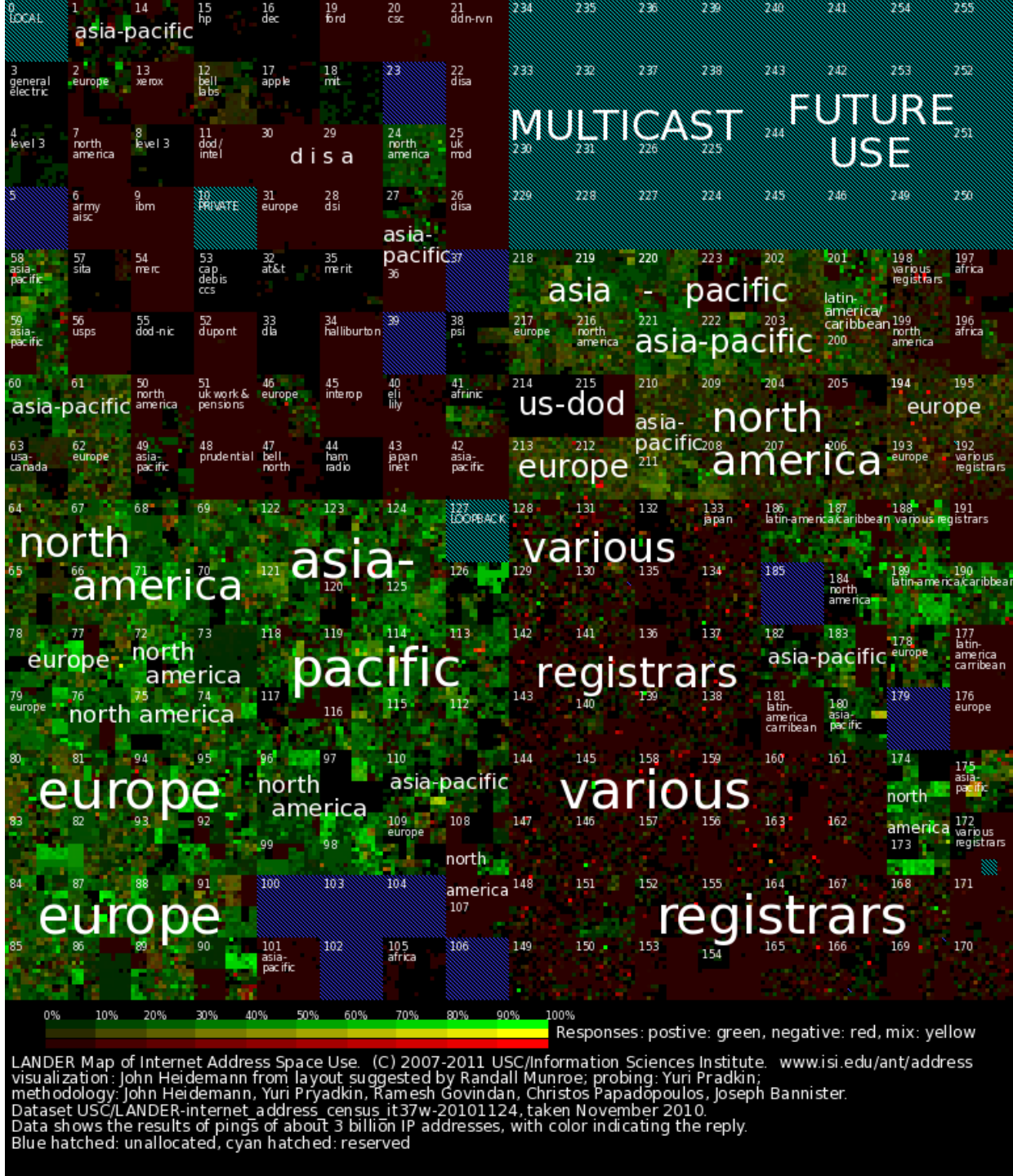


# Multicast Addressing

- **Class D** IP addresses are used for multicast.
- Start with "**1110**" followed by **28-bit group ID**.
- **Fixed** vs **Transient** multicast IP (**logical address**).

- 224.0.0.0: Reserved Class D
- **224.0.0.1**: All multicast devices
- **224.0.0.2**: All multicast routers
- **224.0.0.4**: All DVMRP routers
- 224.0.0.5: All OSPF routers
- 224.0.1.11: IETF-1-Audio
- 224.0.1.12: IETF-1-Video
- 224.0.0.255: Last reserved for routing
- 239.0.0.0: Site-local applications
- 239.255.255.255: Last Class D

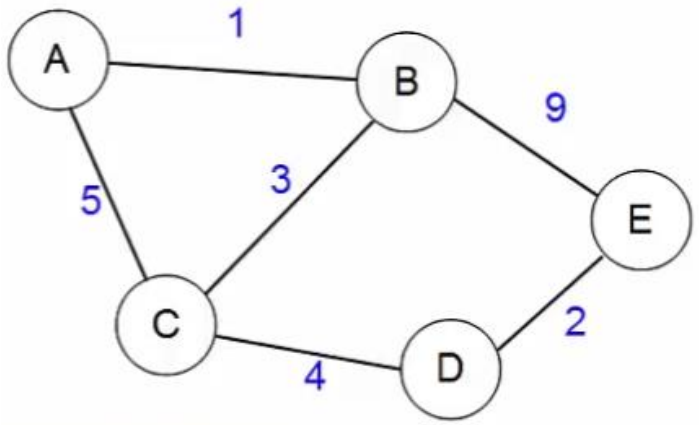


# Distance Vector Routing (eg. RIP)

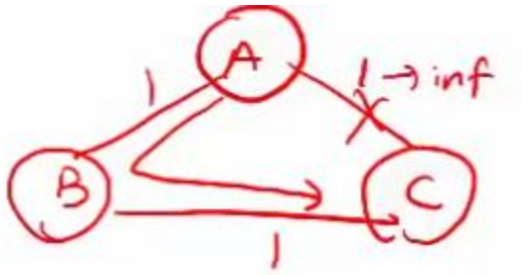
| Dest | Cost | Next Hop |
|---|---|---|
| A | 1 | A |
| C | 3 | C |
| E | 9 | E |

Initial Routing table at B




| Dest | Cost | Next Hop |
|---|---|---|
| A | 1 | A |
| C | 3 | C |
| D | 7 | C |
| E | 9 | E |

Final Routing table at B




Periodic update helps when a route becomes invalid

$$d_x(y) = \min_v\{c(x,v) + d_v(y)\}$$

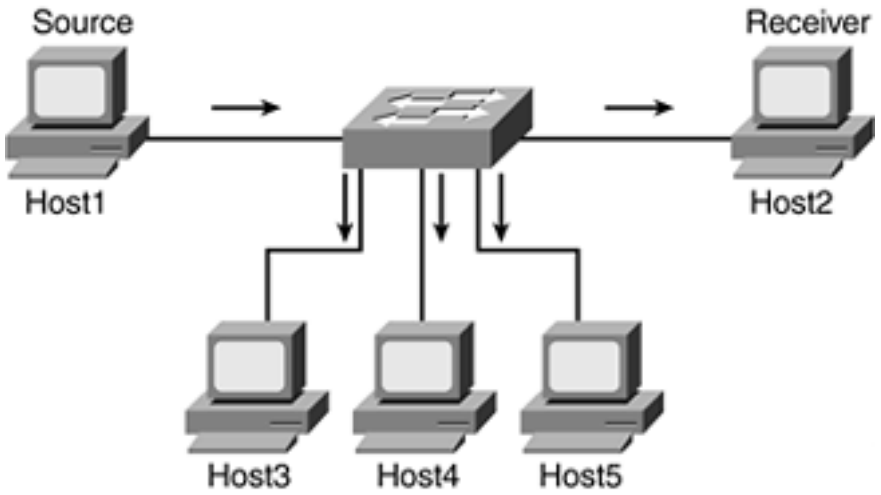
Bellman-Ford distance update equation

- Find the **least cost path** between 2 nodes.
- Also called **Bellman-Ford** algorithm (distributed).
- Each node maintains a routing table.
- Originally used in **ARPAnet, RIP** (now used rarely).

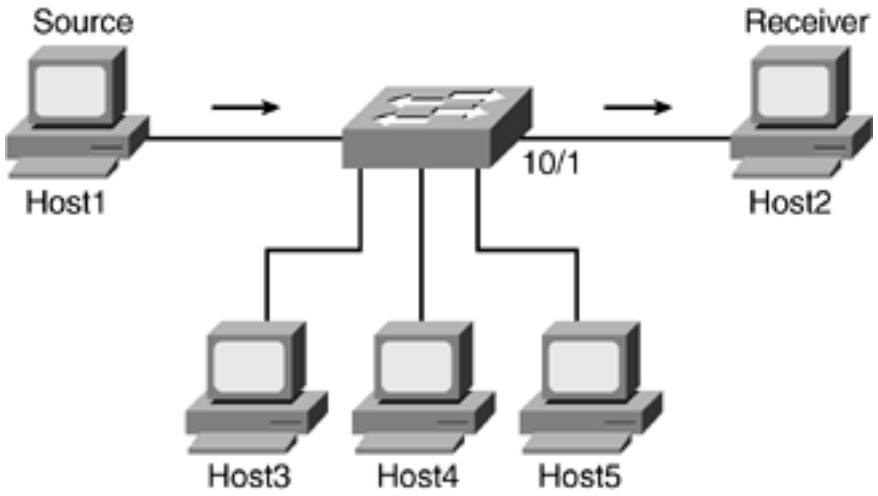
- **Initial**: Distance (cost) to its neighbours is known.
- **Goal**: Distance to all neighbours & next-hop known.
- Routing table info is shared with neighbours (except next-hop).
- On receiving message, routing table updated with min-cost path.
- After N rounds, N+1 hop paths become known.

- **Triggered update**: link / node failure or cost change
- **Periodic update**: Still alive, update DV if some route becomes invalid

# Multicast Flooding

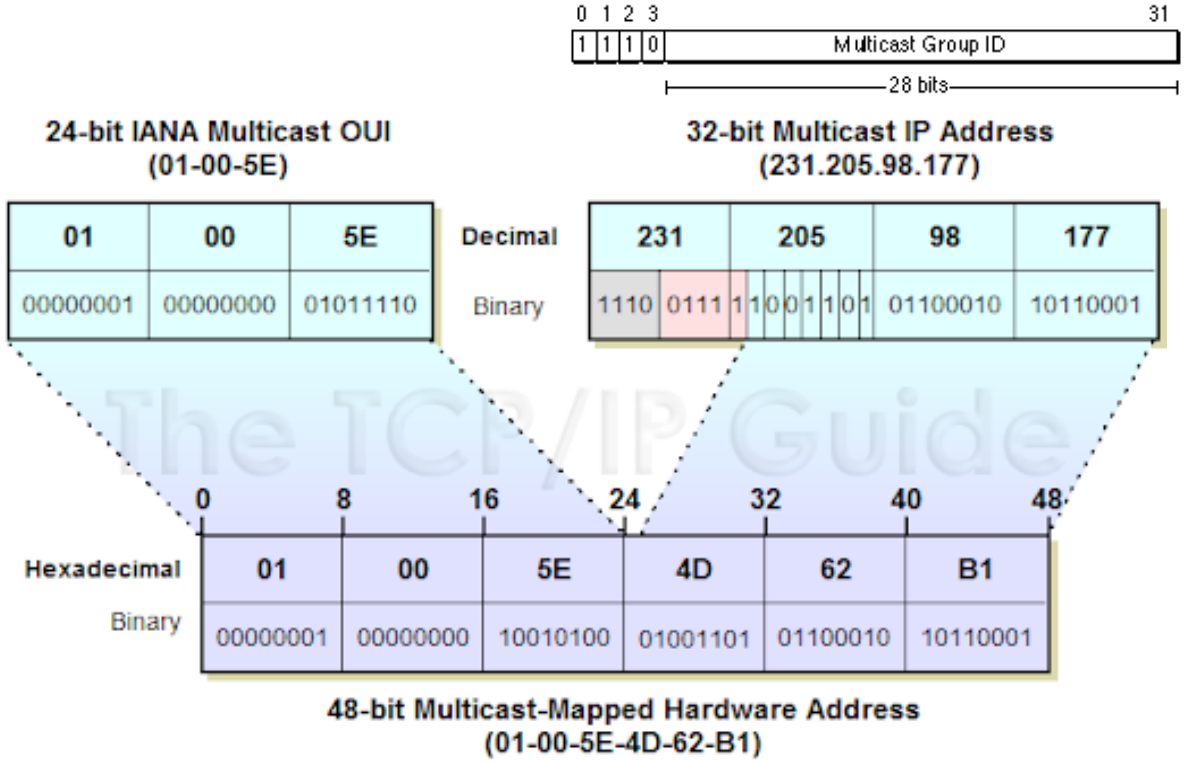



Each Host Receives the Multicast Stream

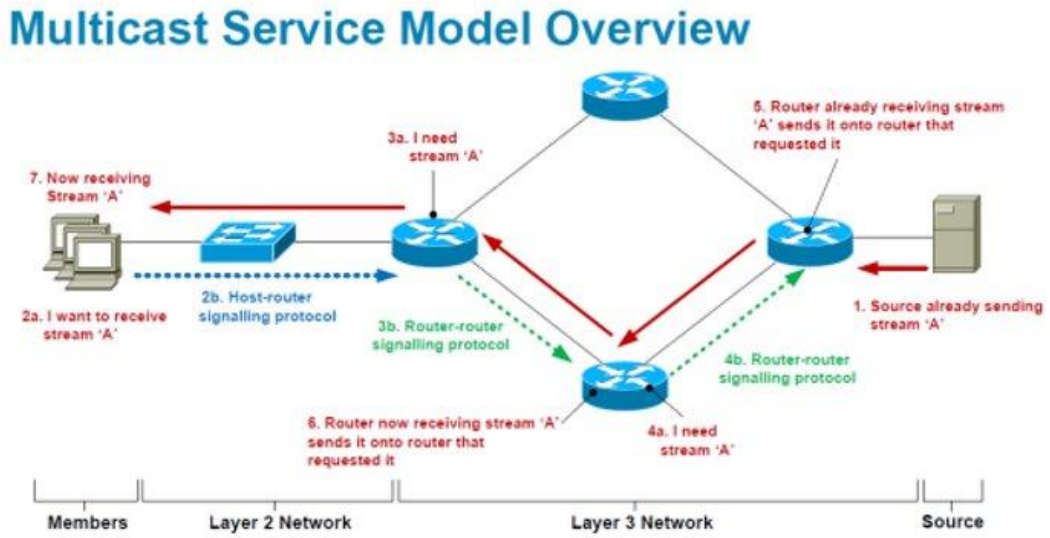


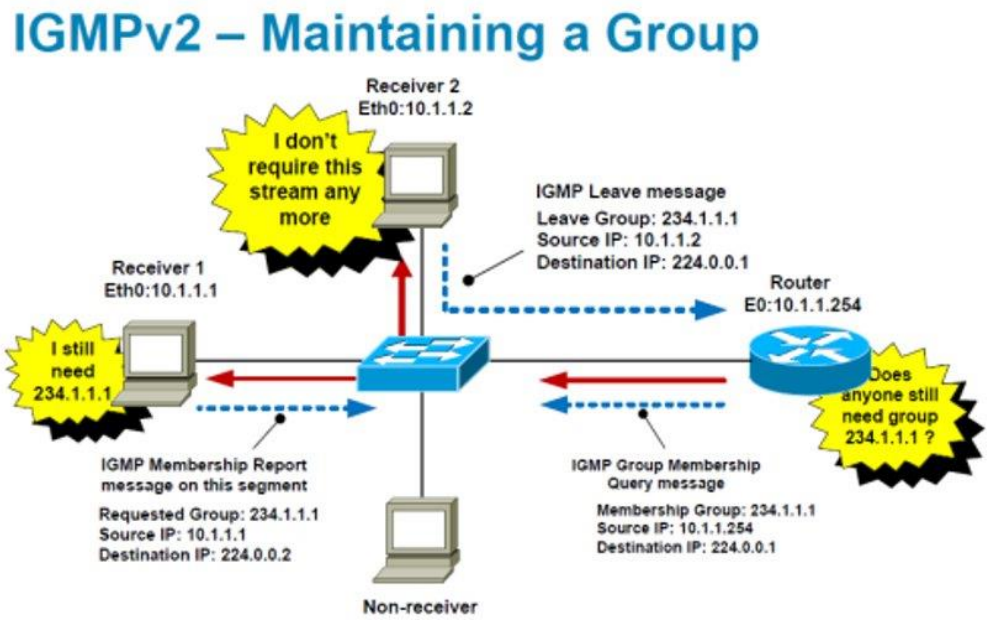

Multicast Stream is filtered by Switch through Multicast MAC address

- Router / Host sends packet on **all interfaces**.
- If router has been seen packet before, its discarded.
- Used on **local network** for multicast communication.
- Filtering can be done with **Multicast MAC address**.



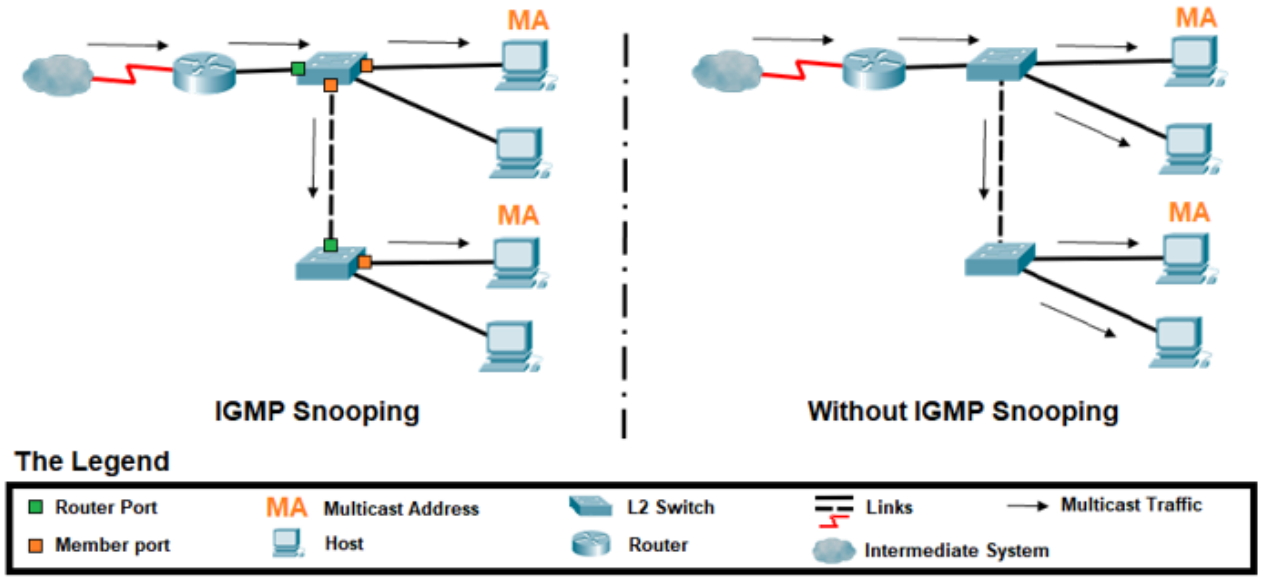
# Internet Group Management Protocol (IGMP)



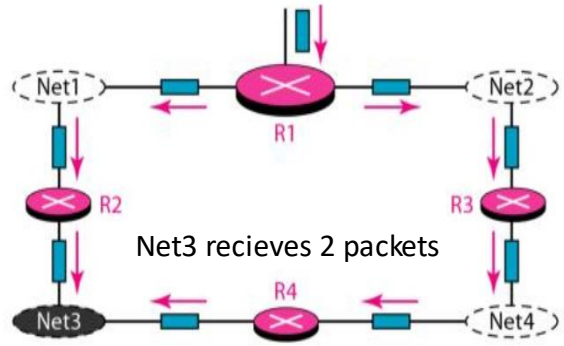



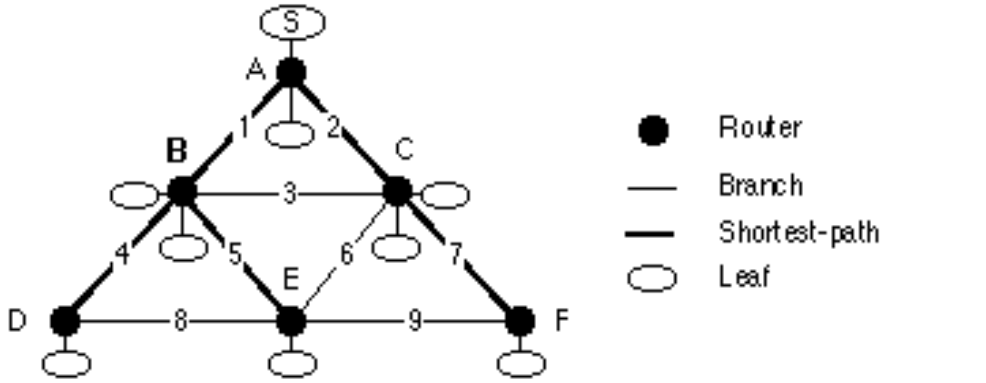

- Hosts tell router about group membership (RFC 1112).
- Router uses this to help route multicast packets.
- Filtering can be done with **IGMP snooping** by switch.

- **Report**: Host says to router, "I want to receive multicast data for X.X.X.X".
- **Query**: Router asks hosts, "Is anone still interested in data for X.X.X.X"?
- Report is sent to address X.X.X.X, and received by other members & router.



# Reverse Path Multicasting (RPM)

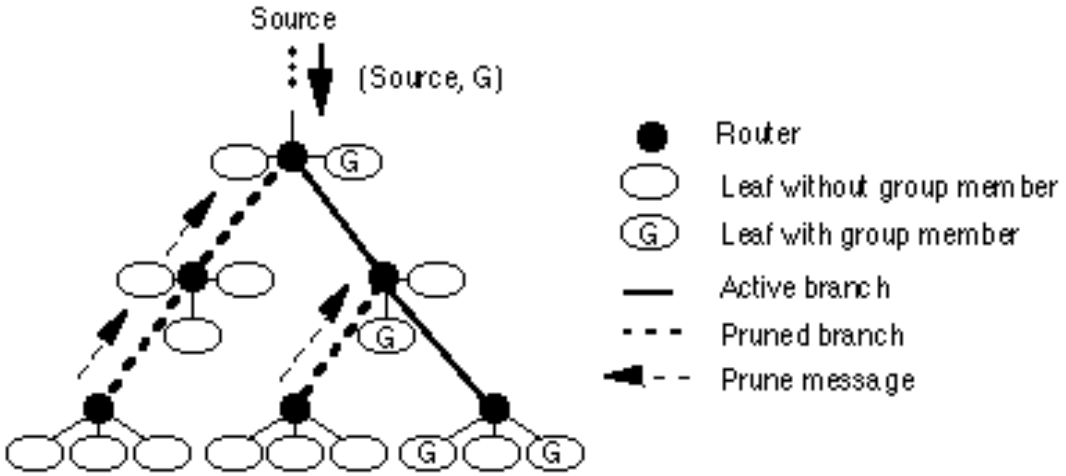


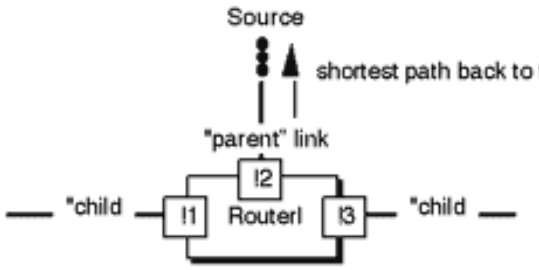

Opt. Reverse Path Broadcasting (**RPB**)

- Forward packet that arrives on **shortest path to source**.
- Router discards packet if it arrives on any other interface. **RPB**
- Delivery tree is **truncated** if leaf subnet has no members. **TRPB**
- **Prune message** is sent if all child links are truncated. **RPM**

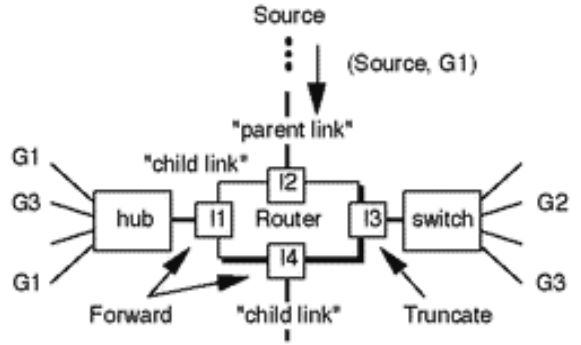
- **Opt**: Forward only if on downstream router's shortest path. **RPB**
- **Duplicates are possible** since shortest path is source-based.




Reverse Path Multicasting (**RPM**)

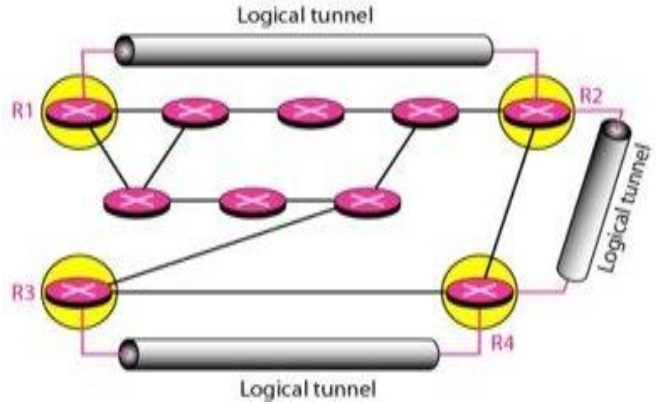


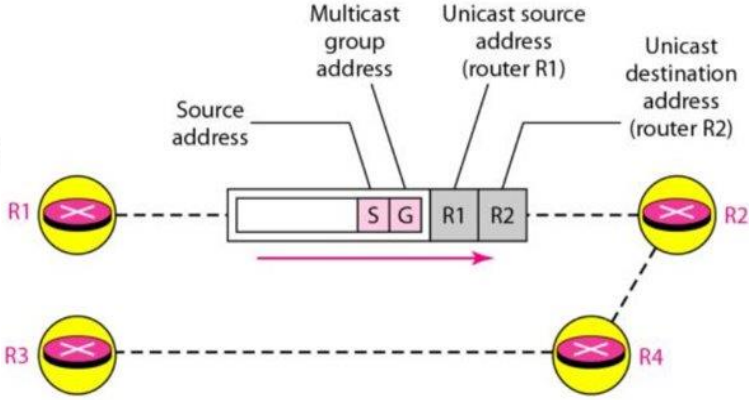

Reverse Path Broadcasting (**RPB**)



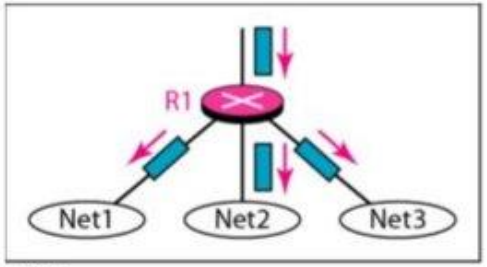

Truncated Reverse Path Broadcasting (**TRPB**)

# DVMRP

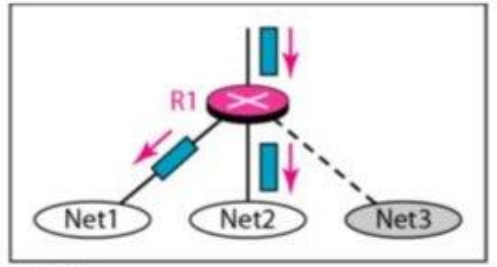


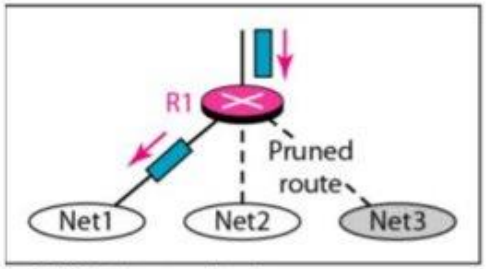

- It is a **distance vector** multicast protocol, like RIP.
- Suitable for use **within** autonomous system.
- **Tunnels** are used between non-multicast routers.
- Routers need to run a unicast protocol too.
- Reverse path multicasting (**RPM**) used between routers.



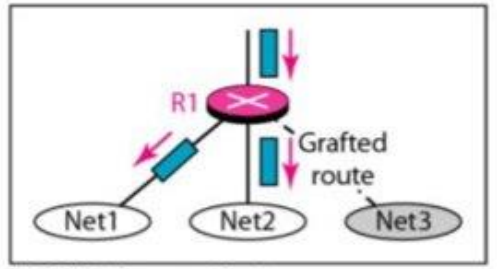
a.RPF



b. RPB



c. RPM (after pruning)



d. RPM (after grafting)

- Intially (S,G) packet is broadcasted using **TRPB**.
- **IGMP** is used to find group members in subnets.
- Routers send **prune** message to parent if subnet has no group member.
- Routers send **graft** message to parent if subnet has new group member.
- **DVMRP**, MOSPF, PIM: within Autonomous System
- MBGP: between Autonomous Systems

| Source Subnet | Subnet Mask | From Gateway | Metric | Status | TTL | InPort | OutPorts |
|---|---|---|---|---|---|---|---|
| 128.1.0.0 | 255.255.0.0 | 128.7.5.2 | 3 | Up | 200 | 1 | 2,3 |
| 128.2.0.0 | 255.255.0.0 | 128.7.5.2 | 5 | Up | 150 | 2 | 1 |
| 128.3.0.0 | 255.255.0.0 | 128.6.3.1 | 2 | Up | 150 | 2 | 1,3 |
| 128.4.0.0 | 255.255.0.0 | 128.6.3.1 | 4 | Up | 200 | 1 | 2 |

DVMRP Routing table

| Source Subnet | Multicast Group | TTL | InPort | OutPorts |
|---|---|---|---|---|
| 128.1.0.0 | 224.1.1.1 | 200 | 1 Pr | 2p 3p |
| | 224.2.2.2 | 100 | 1 | 2p 3 |
| | 224.3.3.3 | 250 | 1 | 2 |
| 128.2.0.0 | 224.1.1.1 | 150 | 2 | 2p 3 |

DVMRP Forwarding table

# DVMRP Datagrams

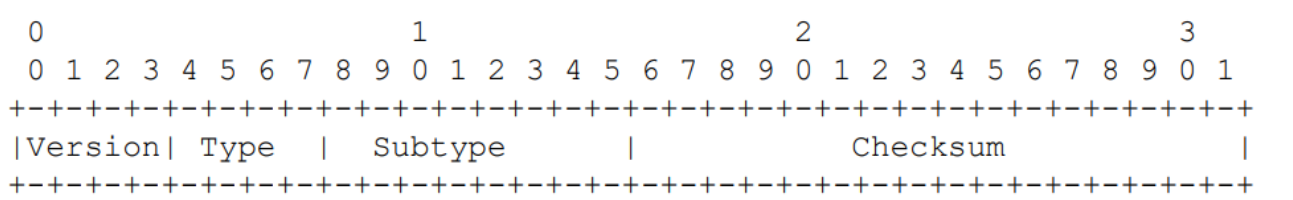
- DVMRP uses **IGMP** to exchange routing datagrams (type 3).
- Message is a stream of **tagged data** (key=value, … max 512B).
- Routers provide **periodic** and **triggered** updates.
- Messages sent to multicast address **224.0.0.4** (TTL=1).

**Subtypes**

- **Request**: request route to sources
- **Response**: provide route to sources
- **Non-membership report**: prune path for T seconds (no member)
- **Non-membership cancellation**: graft path (new member)

**Commands**

- NULL, Flags0, Infinity, Metric
- Address Family Indicator (AFI), Subnet mask
- Destination Address (DA)
- Requested Destination Address (RDA)
- Non Membership Report (NMR)
- Non Membership Report Cancel (NMR Cancel)




**DVMRP header**

```
Subtype 1,
AFI 2,  Metric 2, Infinity 16, Subnet Mask 255.255.255.0
{2} {2} {4} {2}   {6} {16}     {3} {1} {255} {255} {255} {0}

DA Count=1 [128.2.251.231]
{7} {1} {128} {2} {251} {231}
```

**Response** of route for **128.2.251.231** with metric **2**, INF=16, SM=255.255.255.0

```
Subtype 1,
AFI 2,  Metric 2, Infinity 16, Subnet Mask 255.255.255.0
{2} {2} {4} {2}   {6} {16}     {3} {1} 255} {255} {255} {0}

DA Count=2 [128.2.251.231] [128.2.236.2]
{7} {1} {128} {2} {251} {231} {128} {2} {236} {2}
```

**Response** of route for **128.2.251.231** & **128.2.236.2** with metric **2**, INF=16, SM=255.255.255.0

```
Subtype 2, AFI 2,  RDA Count = 0
           {2} {2} {8} {0}
```

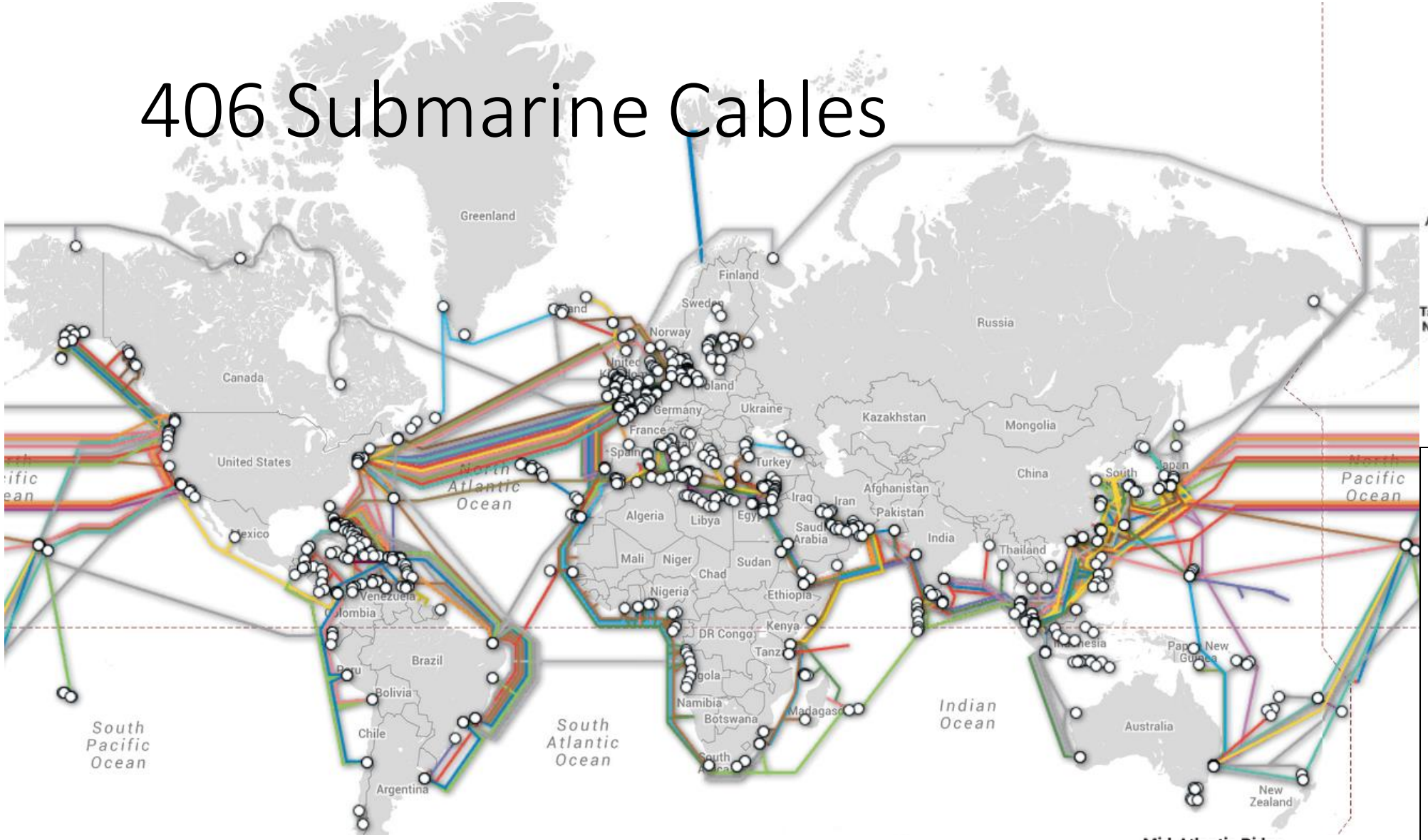
**Request** all routes (to source).

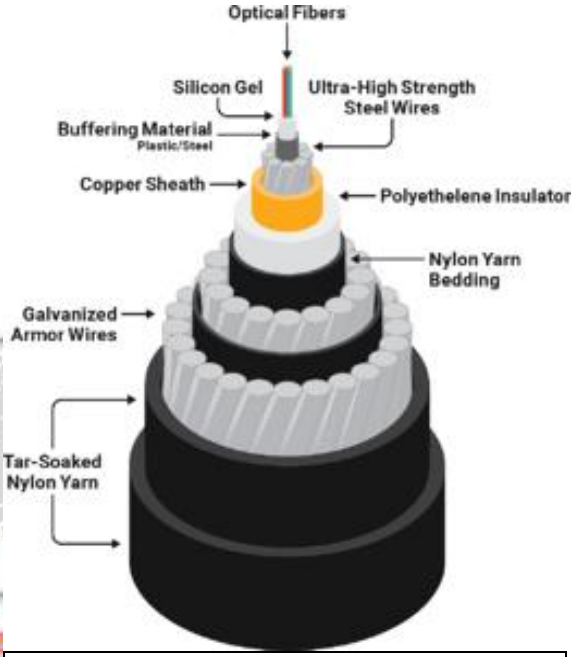
```
Subtype 3,
AFI 2,  NMR Count = 3 [224.2.3.1, 20]
{2} {2} {10} {3} {224} {2} {3} {1} {0} {0} {0} {20}

[224.5.4.6, 20] [224.7.8.5, 40]
{224} {5} {4} {6} {0} {0} {0} {20} {224} {7} {8} {5} {0} {0} {0} {40}
```

**NMR** for groups **224.2.3.1** & **224.5.4.6** (20s), **224.7.8.5** (40s)

# 406 Submarine Cables



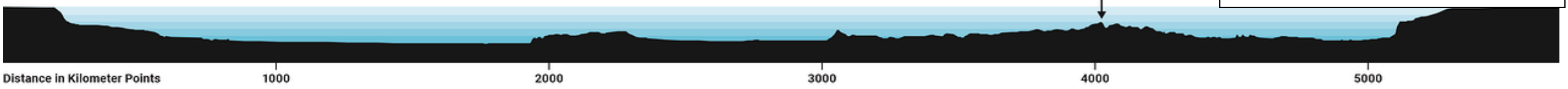

Minimum design life of 25 years.

Satellites account for 0.37% of all U.S. international capacity.

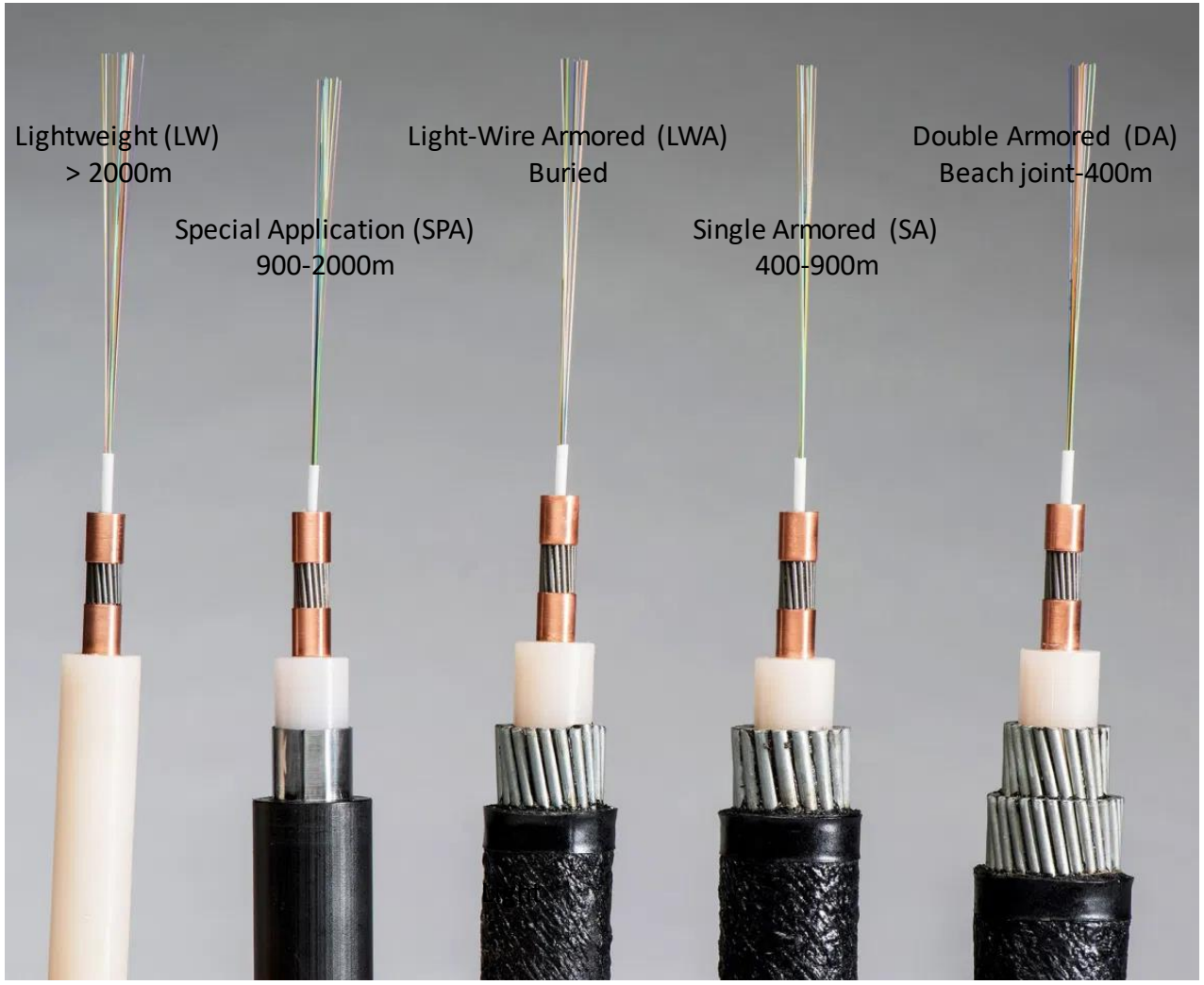
The new MAREA cable is capable of carrying 208 Tbps.

Google, Facebook, Microsoft, and Amazon are major investors in new cable.

Total 1.2 million km (2020)



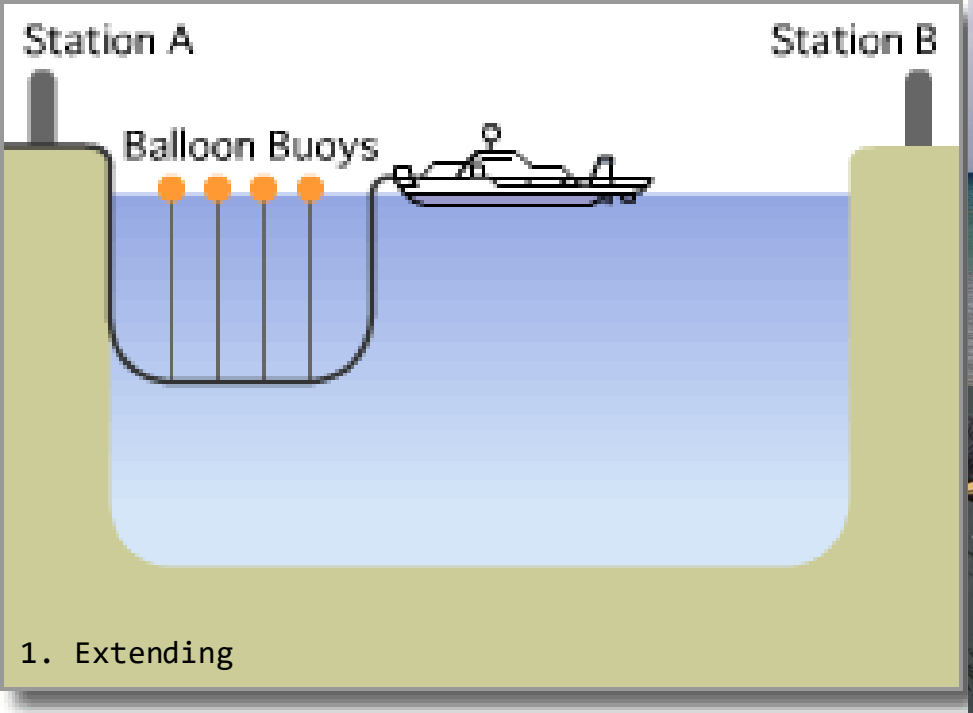
# Manufacturing & Deployment



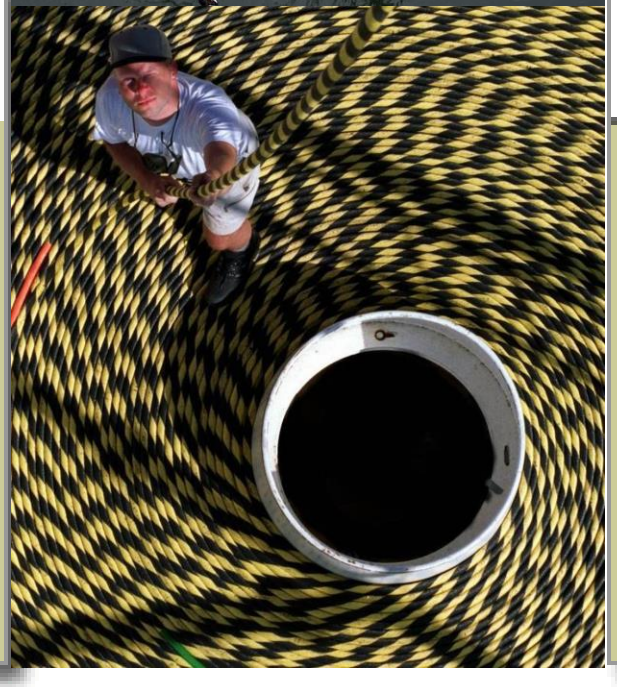

Subcom Fiber Optic Cable Kit.

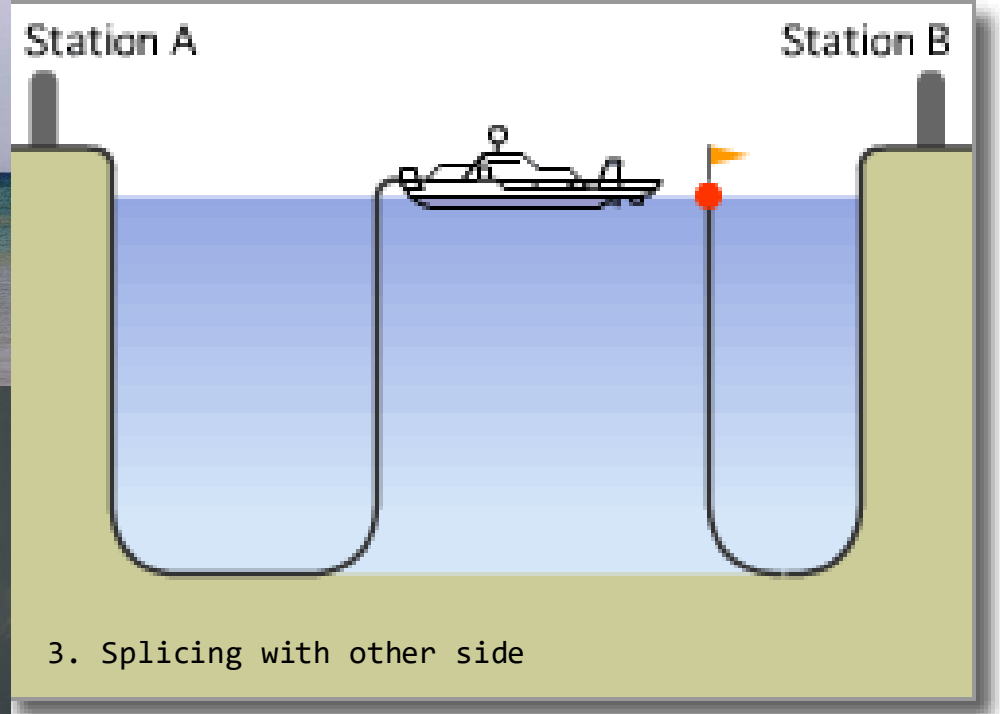
- Japanese NEC developed 20 fiber pair (40) cable. (2020)
- Google announced a cable with 24 pairs of optical fibers.
- Bandwidth of 12-pair **Dunant** is declared at 250 Tbps.
- DWDM allows 100 wavelengths over a single fiber.

- Largest manufacturers:
- Alcatel Submarine Networks (ASN) (France)
- TE SubCom (USA)
- Nippon Electric Company (NEC) (Japan)
- Prysmian (Italy)
- Nexans (France)
- Hengtong (China)
- Zhongtian (China)

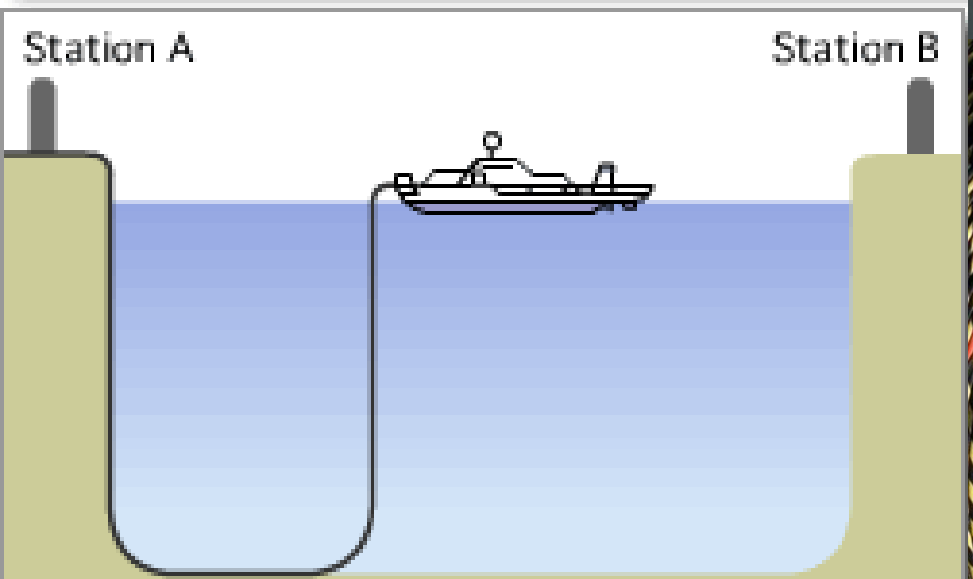



1. Extending

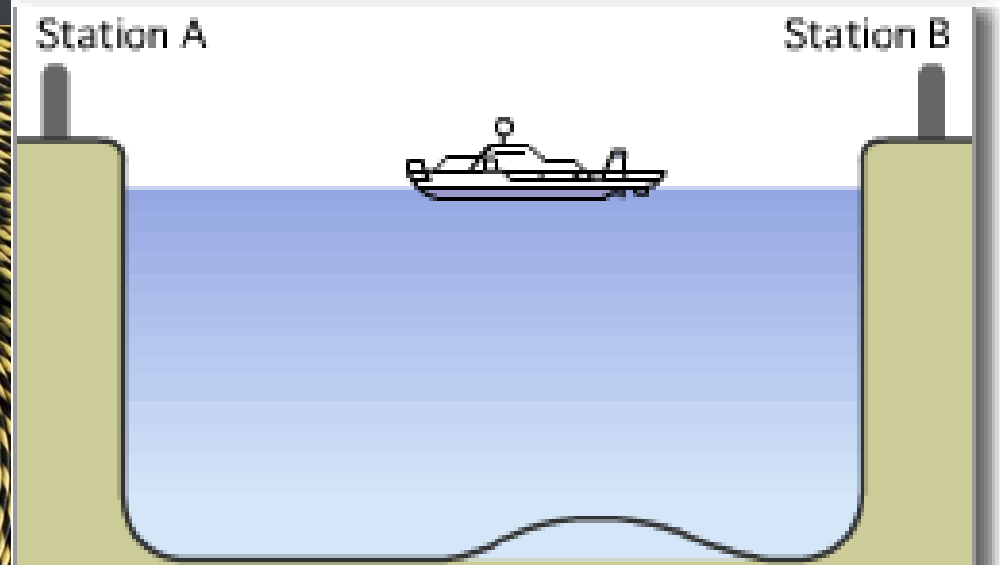




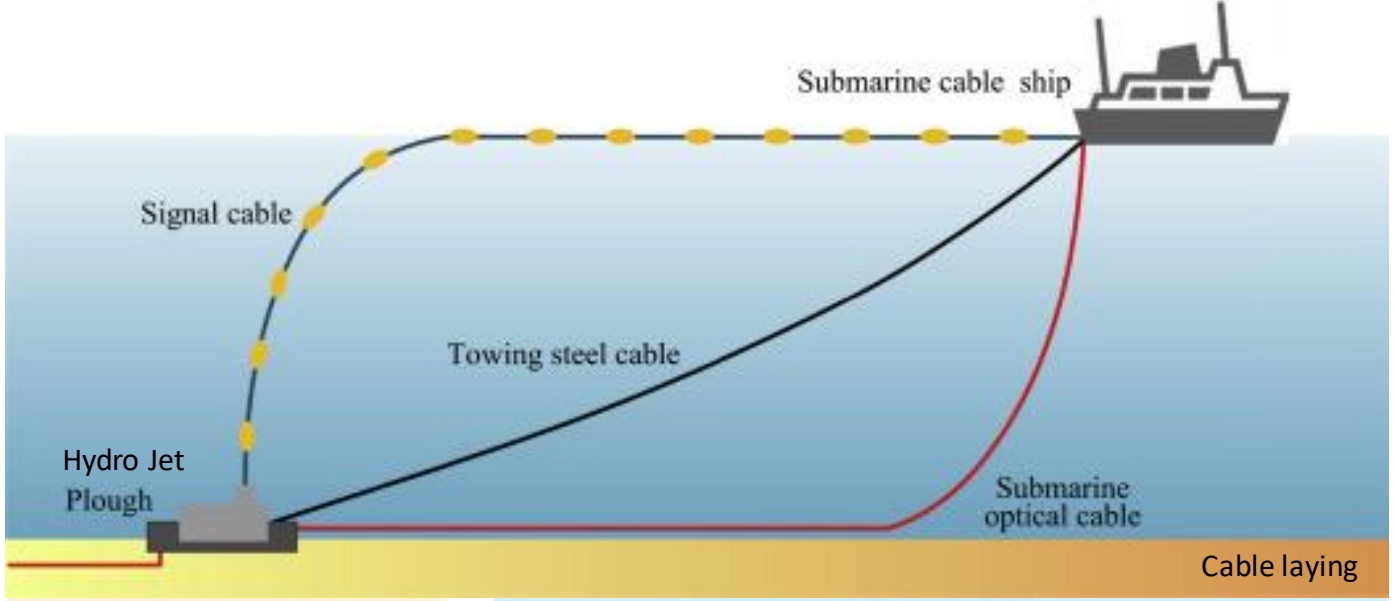

3. Splicing with other side




2. Dropping

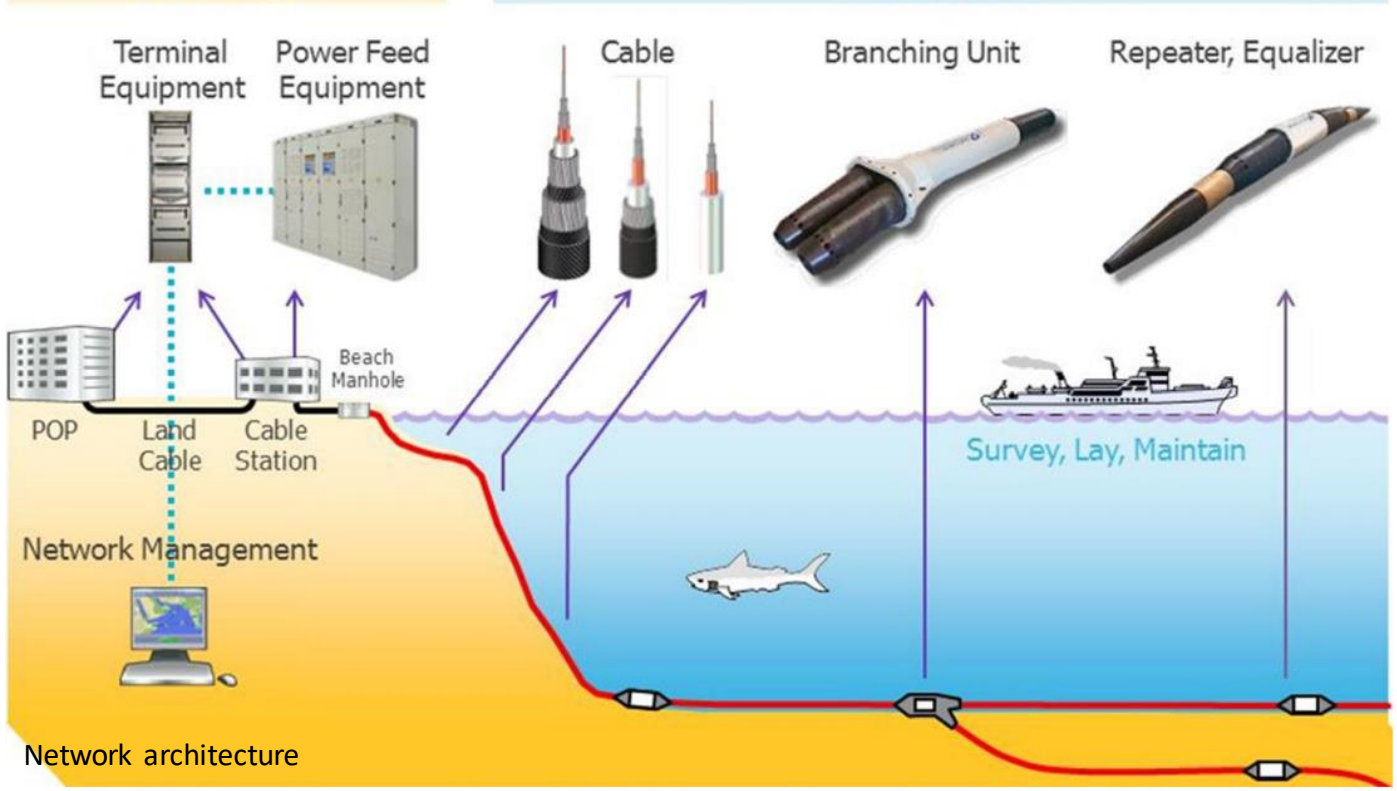



4. Dropping




Cable laying

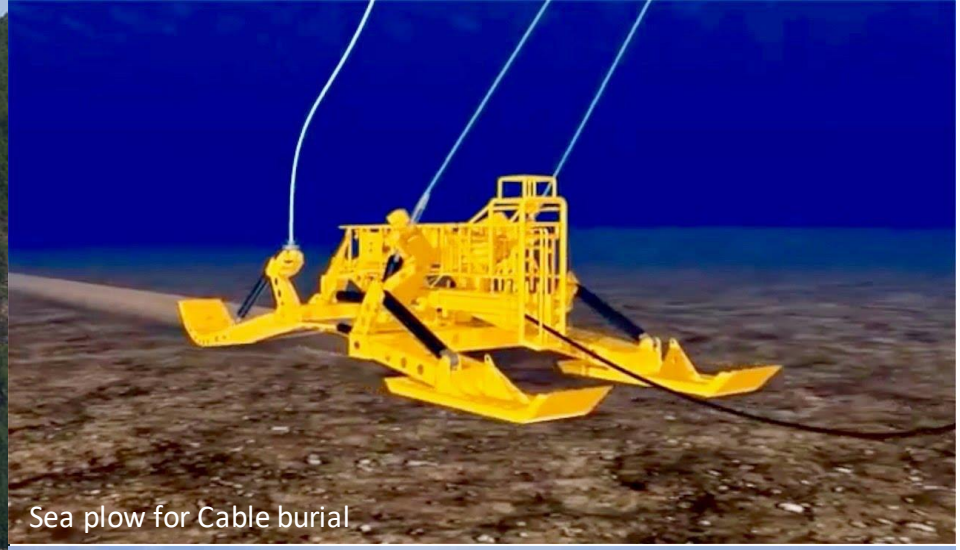
NEC repeaters with four signal amplifiers are located at the OCC factory in Japan.



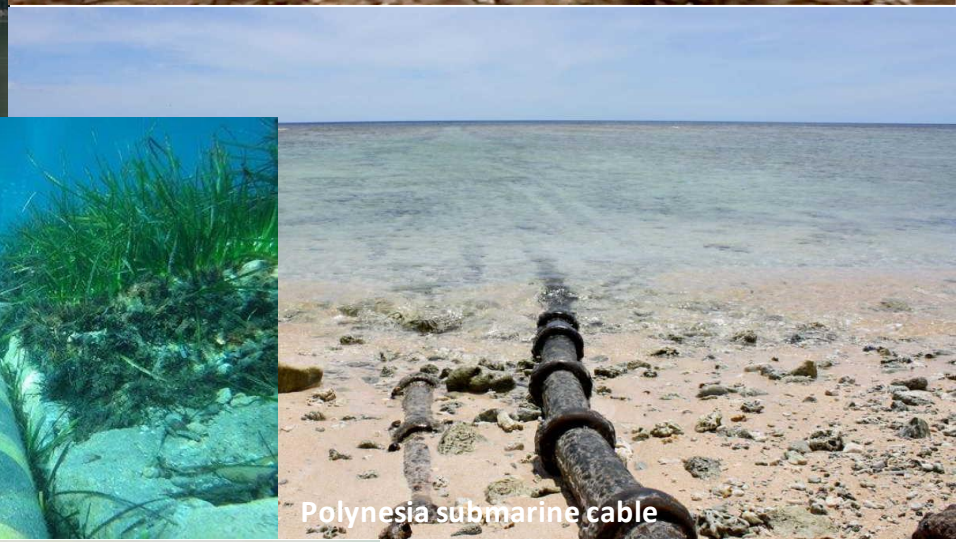

Network architecture

Alcatel Submarine Networks Optical Repeater

Installation ship



Sea plow for Cable burial



Polynesia submarine cable

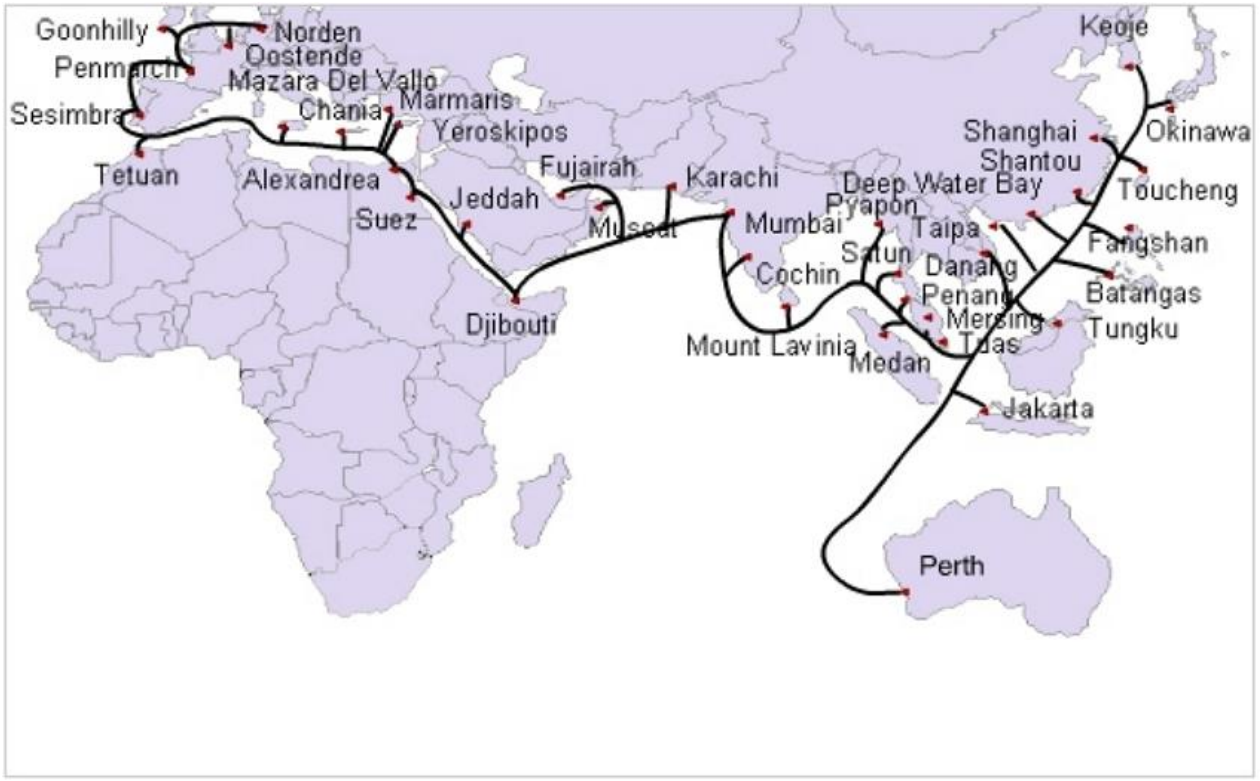
Survey ship

Maintenance ship

# FEA

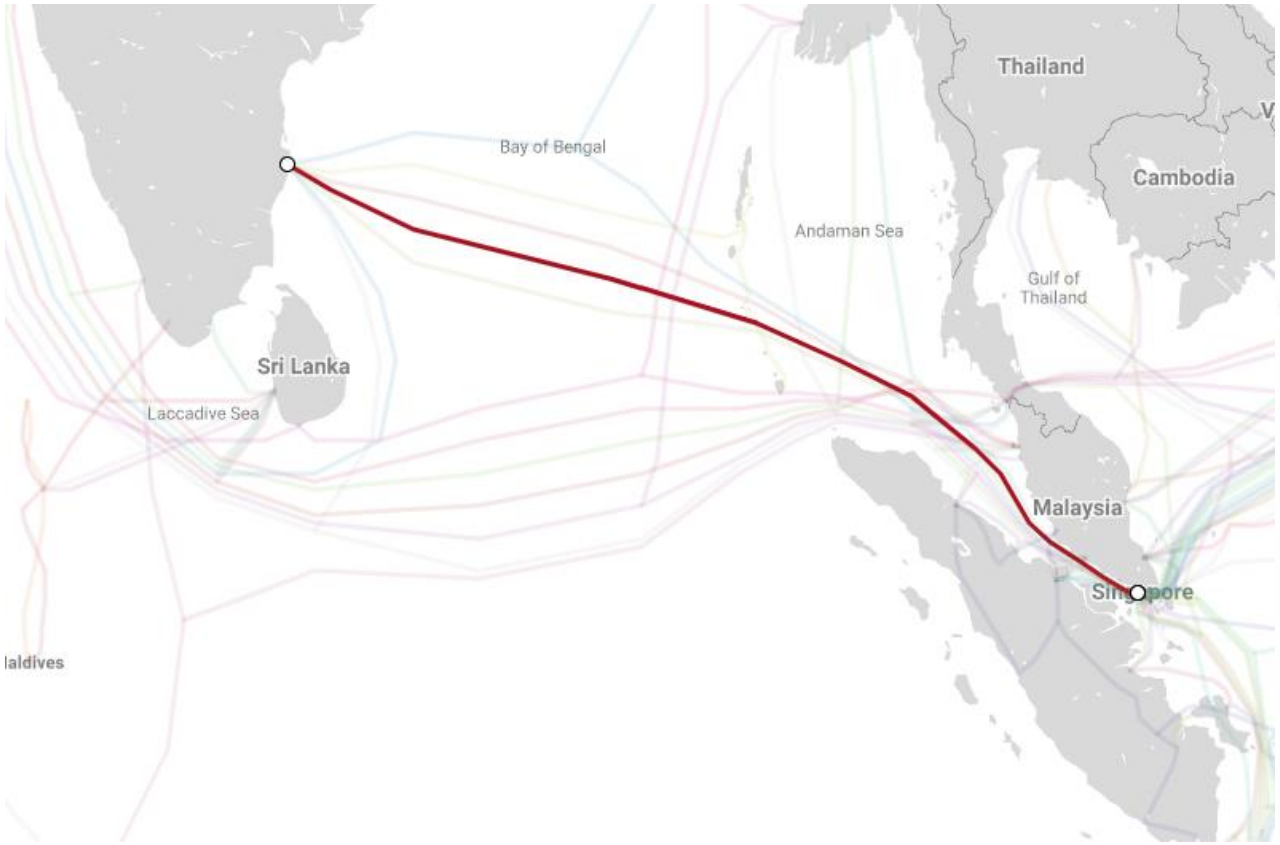

- The FLAG Europe Asia (Fiber-optic Link Around Globe).
- Length: 28,000km, Capacity: 80Gbps (1997)
- Operators: Global Cloud Xchange (RCOM) (1)
- CLS: Chennai (Tata Comm.) (18)

# SEA-ME-WE 3



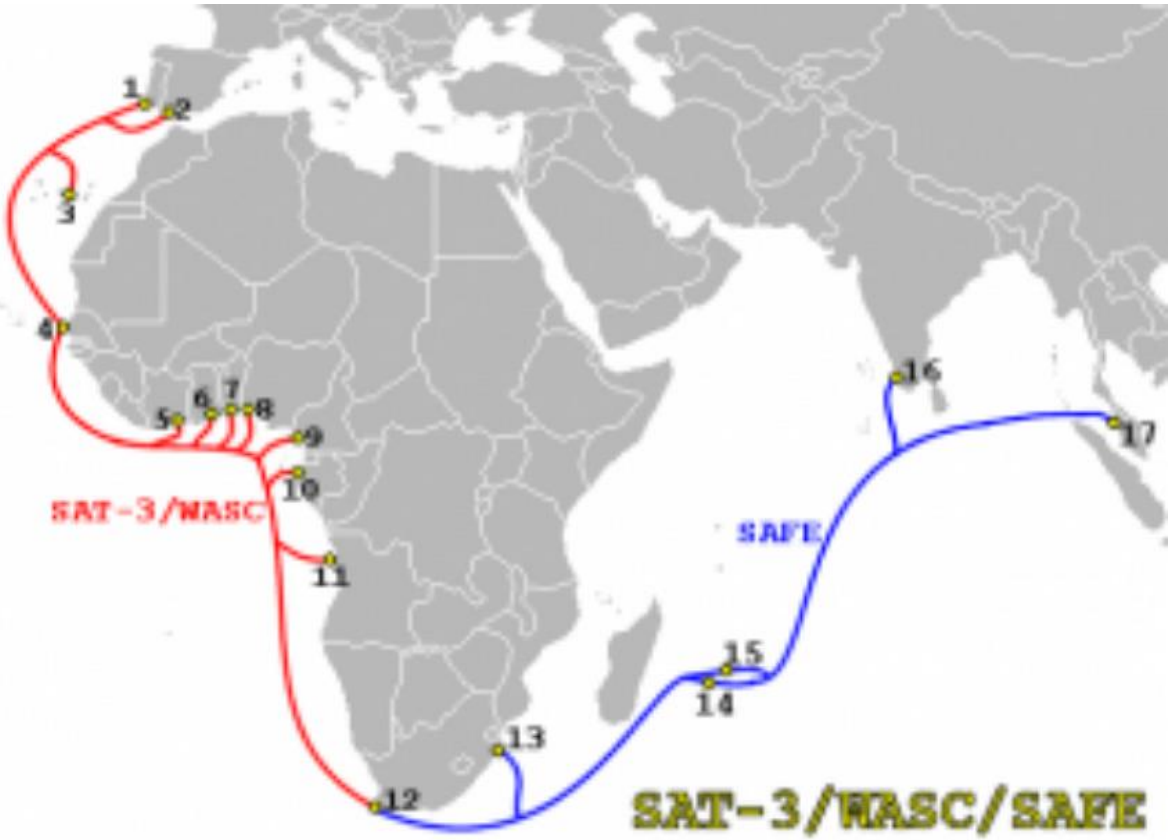

- The South-East Asia Middle East Western Europe 3.
- Length: 39,000km, Capacity: 100G (1999)
- Operators: BSNL (92)
- CLS: Mumbai (Tata Comm.), Kochi (Tata Comm.) (39)

# I2ICN




- The i2 Cable Network.
- Length: 3,100km, Capacity: 8.4Tbps (2002)
- Operators: Bharti Airtel (2)
- CLS: Chennai (Airtel) (2)

# SAFE

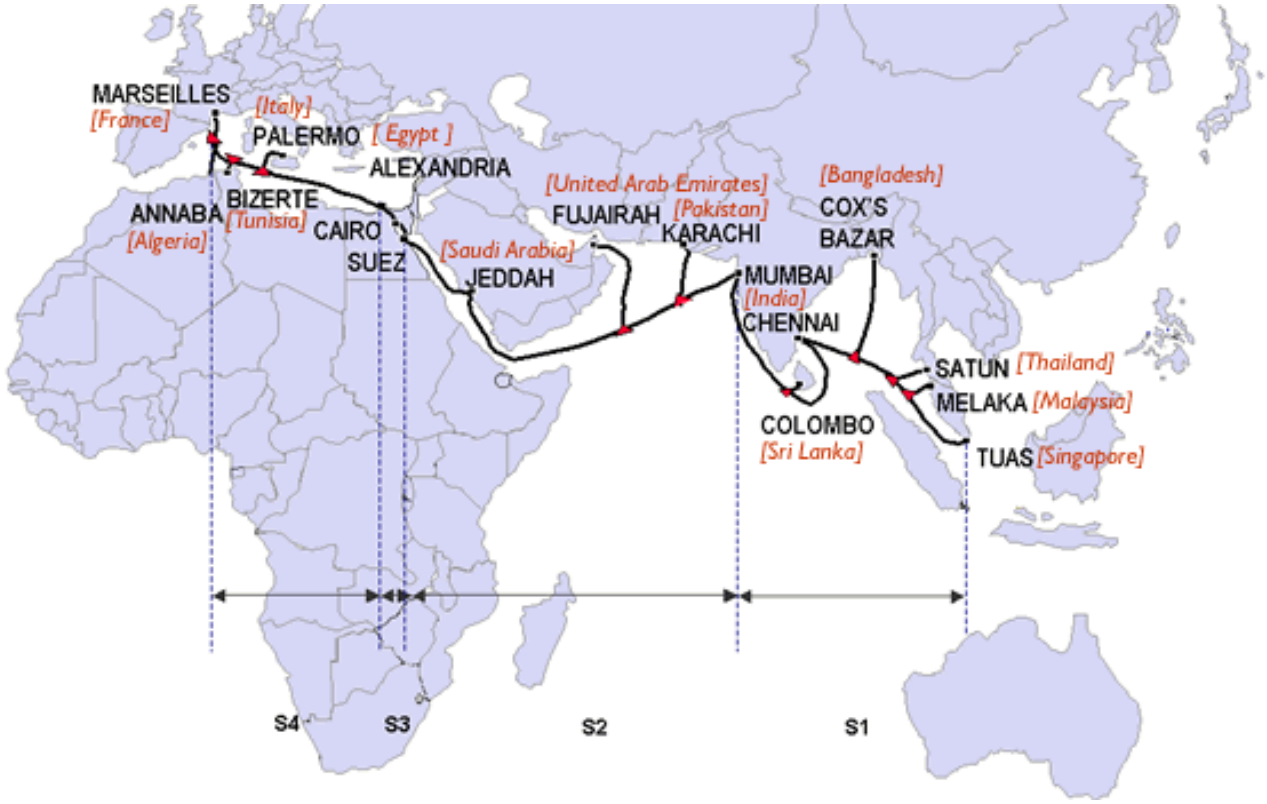



- The South Africa Far East.
- Length: 13,500km, Capacity: 130Gbps (2002)
- Operators: Tata Comm. (30)
- CLS: Cochin (Tata Comm.) (6)

# TIC


- The Tata Indicom Cable.
- Length: 3,175km, Capacity: 5.1Tbps (2004)
- Operators: Tata Comm. (1)
- CLS: Chennai (Tata Comm.) (2)

# SEA-ME-WE 4

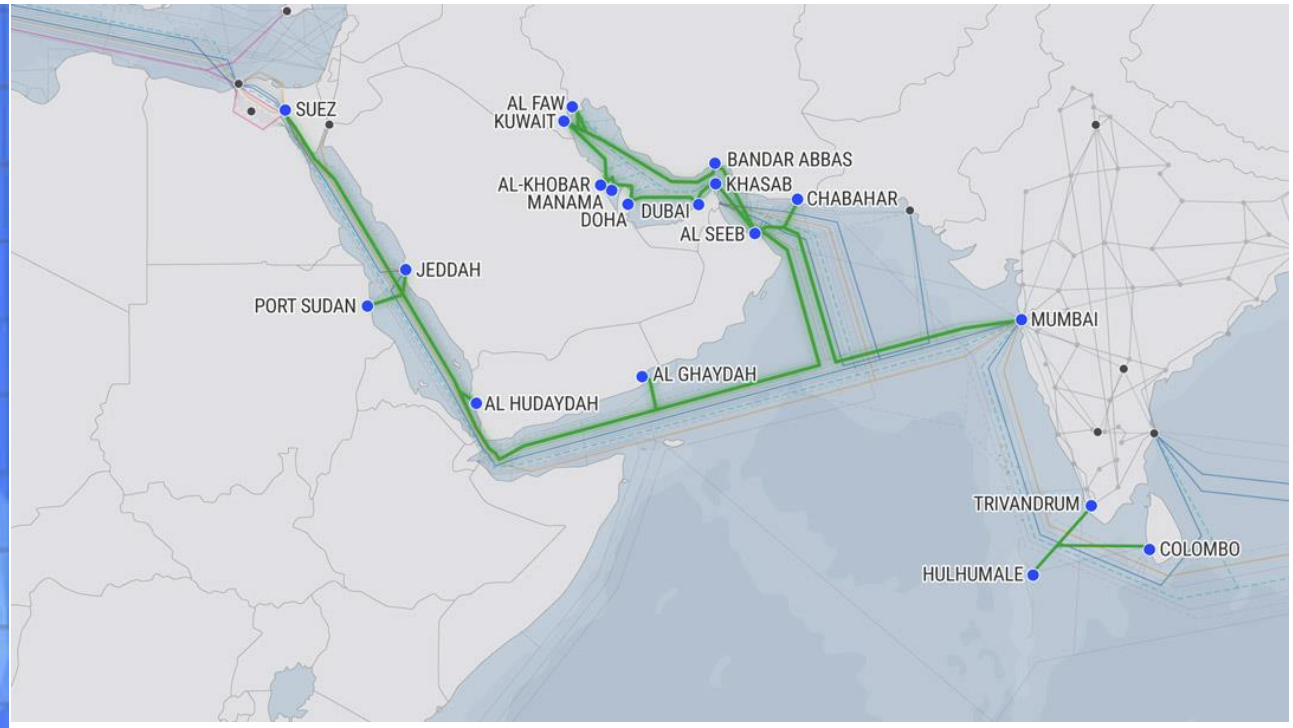



- The South East Asia-Middle East-West Europe 4.
- Length: 18,800km (4), Capacity: 4.6Tbps (2005)
- Operators: Tata Comm., Bharti Infotel (16)
- CLS: Mumbai (Airtel), Chennai (Airtel) (17)

# BLCS

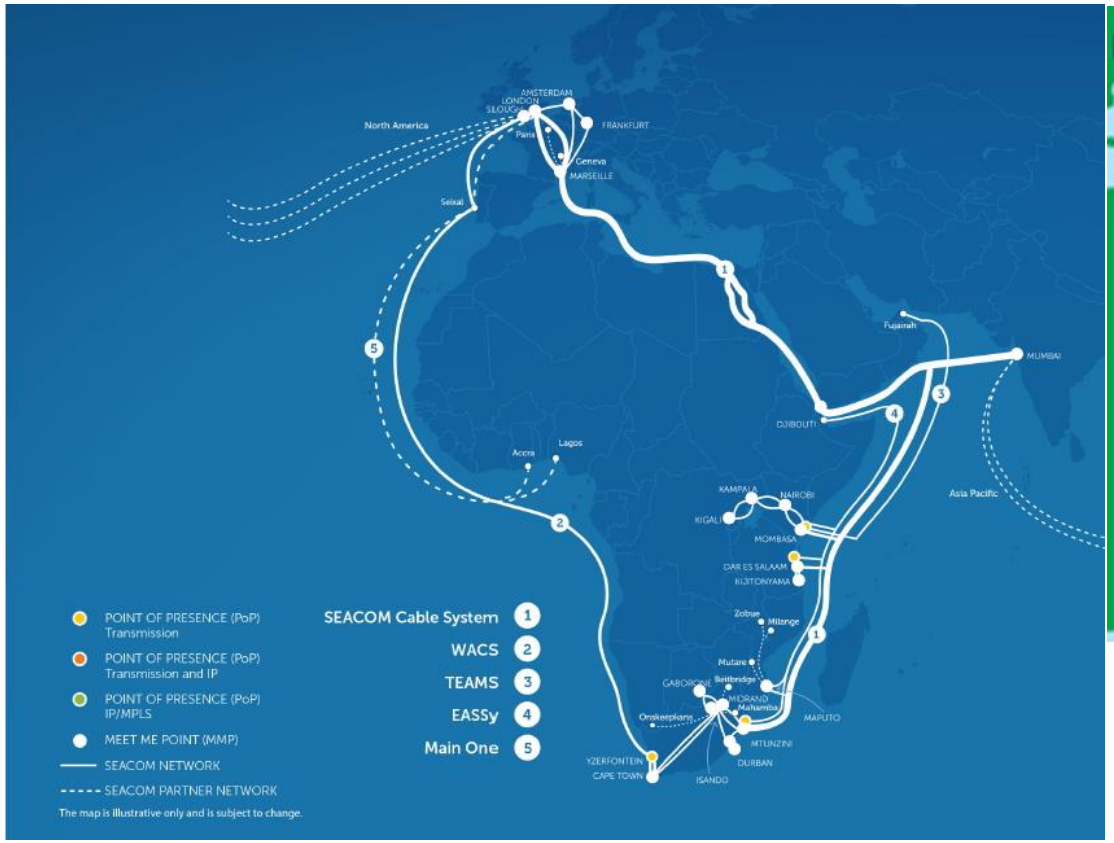

- The Bharat Lanka Cable System.
- Length: 320km, Capacity: 1Tbps (2006)
- Operators: BSNL(2)
- CLS: Tuticorin (Reliance) (2)

# FALCON



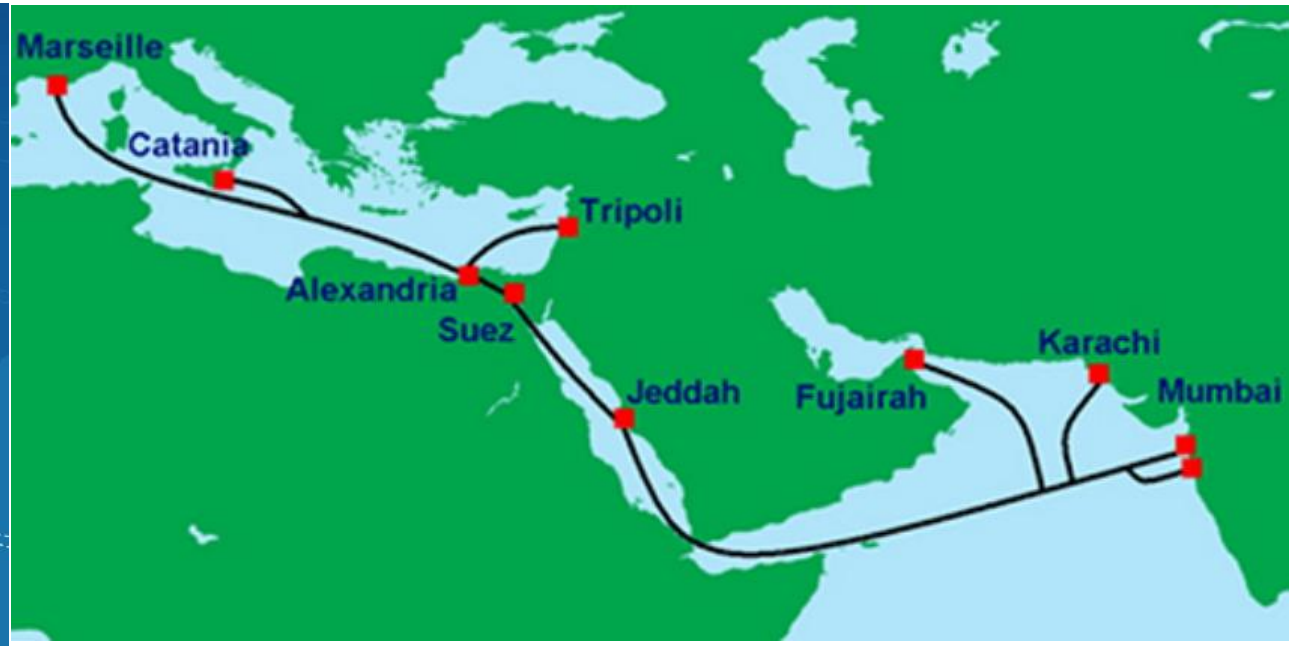

- The FLAG Alcatel-Lucent Optical Network.
- Length: 11,859km, Capacity: 2.56Tbps (2006)
- Operators: Global Cloud eXchange (16)
- CLS: Mumbai (Reliance) (17)

# SEACOM




- The SEACOM Cable.
- Length: 17,000km, Capacity: 1.5Tbps (2009)
- Operators: (5)
- CLS: Mumbai (Tata Comm. / VSNL) (9)

# IMEWE

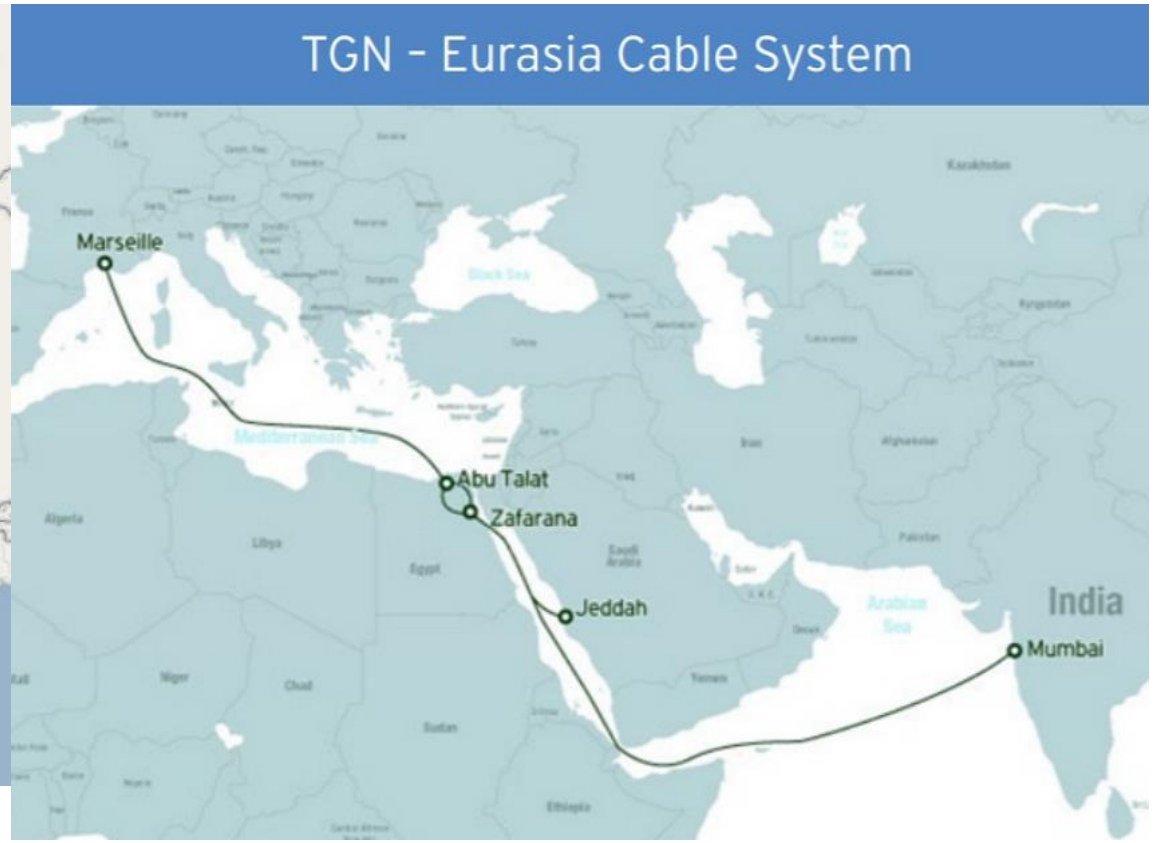



- The India Middle-East Western-Europe.
- Length: 12,091km, Capacity: 5.6Tbps (2010)
- Operators: Bharti Airtel, Tata Comm. (9)
- CLS: Mumbai (Tata Comm.) (10)

# EIG

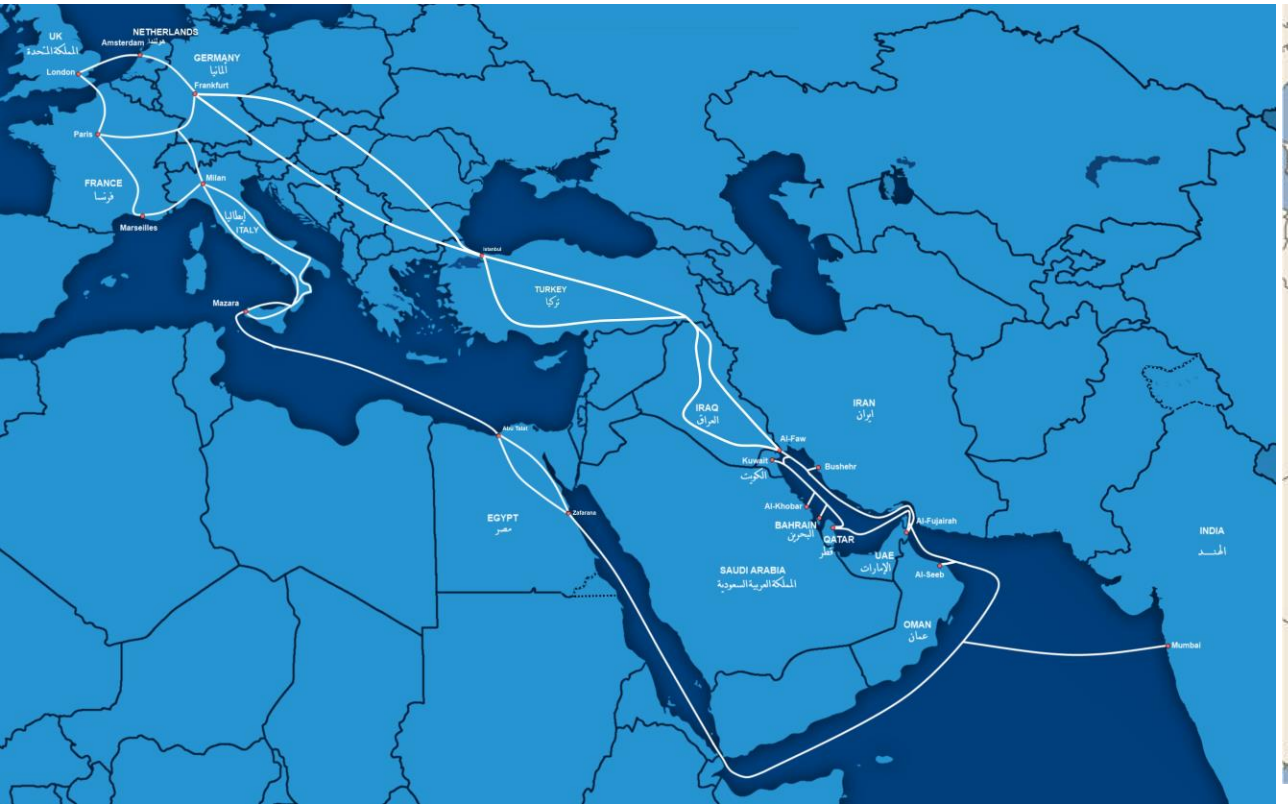

- The Europe India Gateway.
- Length: 15,000km (4), Capacity: 3.8Tbps (2011)
- Operators: Bharti Airtel, BSNL (16)
- CLS: Mumbai (Airtel) (12)

# TGN-EA



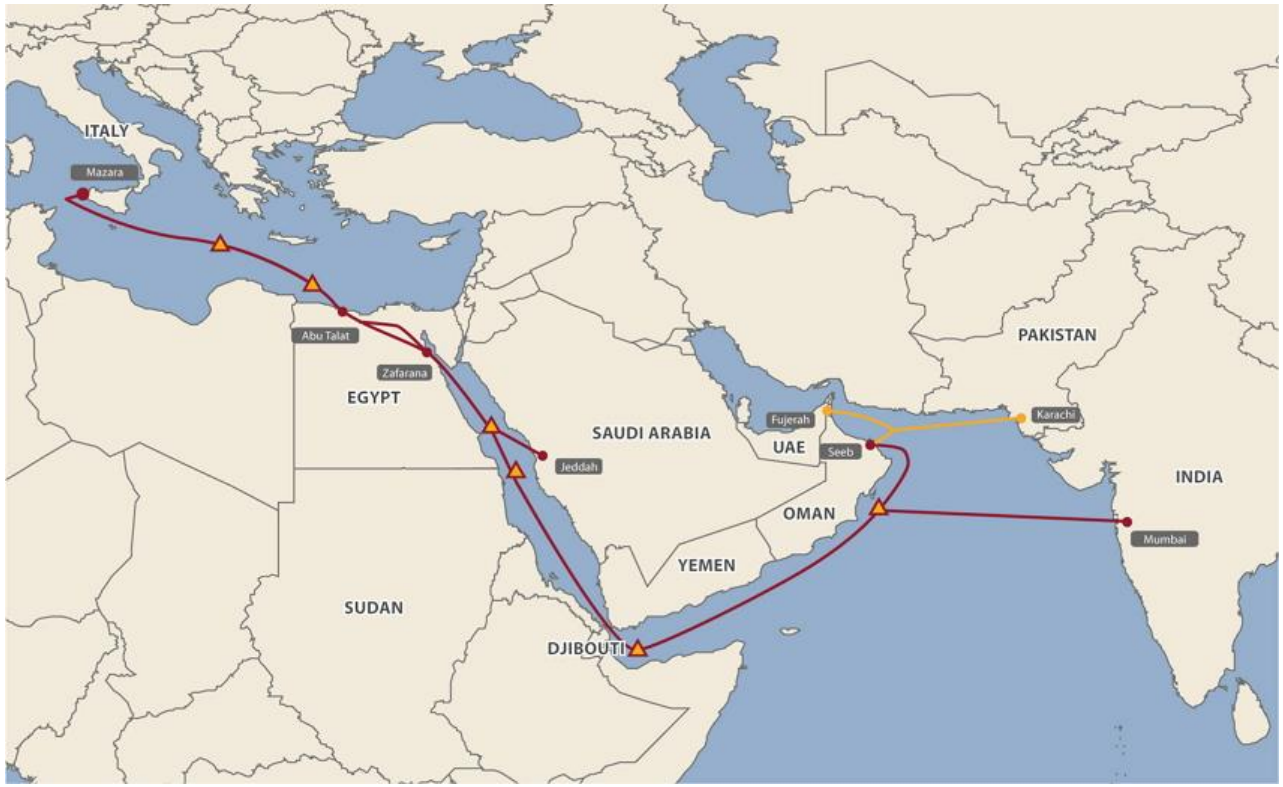

- The Tata Global Network-Eurasia.
- Length: 9,280km, Capacity: 1.28Tbps (2012)
- Operators: Tata Comm. (1) (RTD: 92ms)
- CLS: Mumbai (Tata Comm. / VSNL) (5)

# GIBY



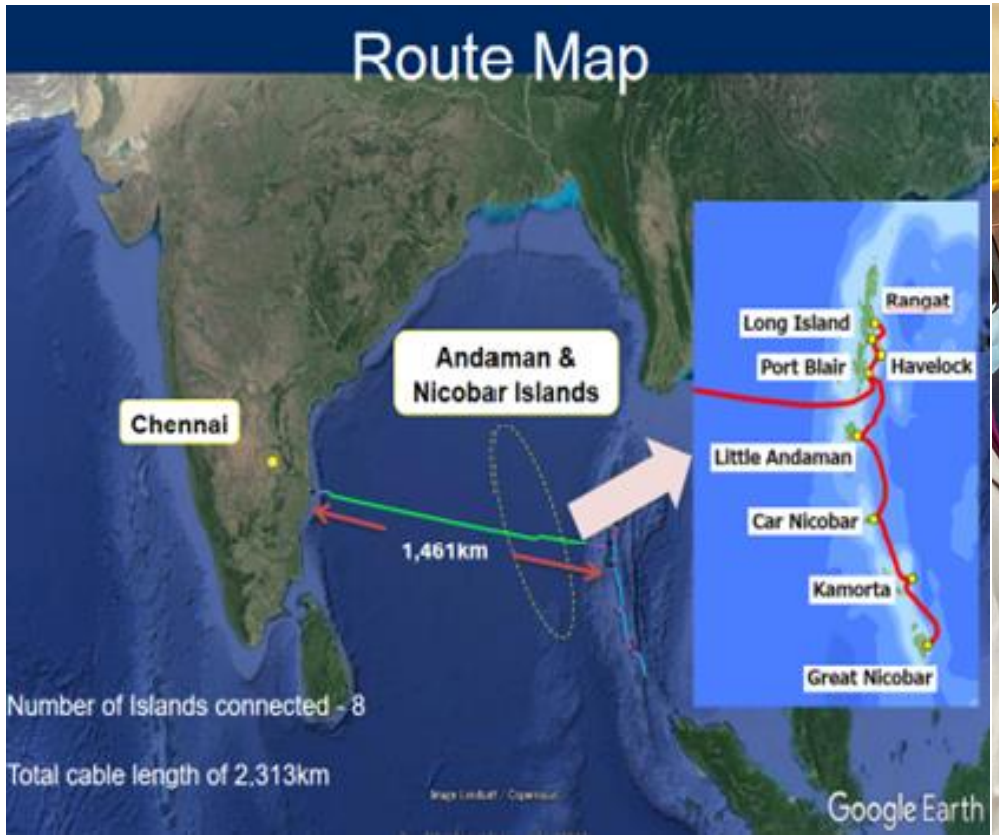

- The Gulf Bridge International.
- Length: ?km, Capacity: 5.6Tbps (2012)
- Operators: Bharti Airtel (?)
- CLS: Mumbai (Sify Tech.) (10)

# MENA




- The Middle East North Africa.
- Length: 8,800km, Capacity: 5.8Tbps (2014)
- Operators: Bharti Airtel (?)
- CLS: Mumbai (Sify Tech.) (7)

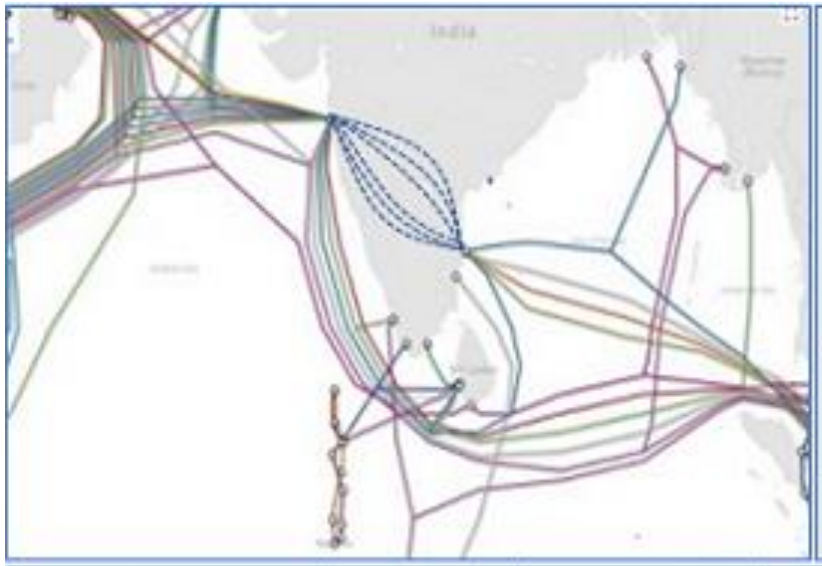
# CANI

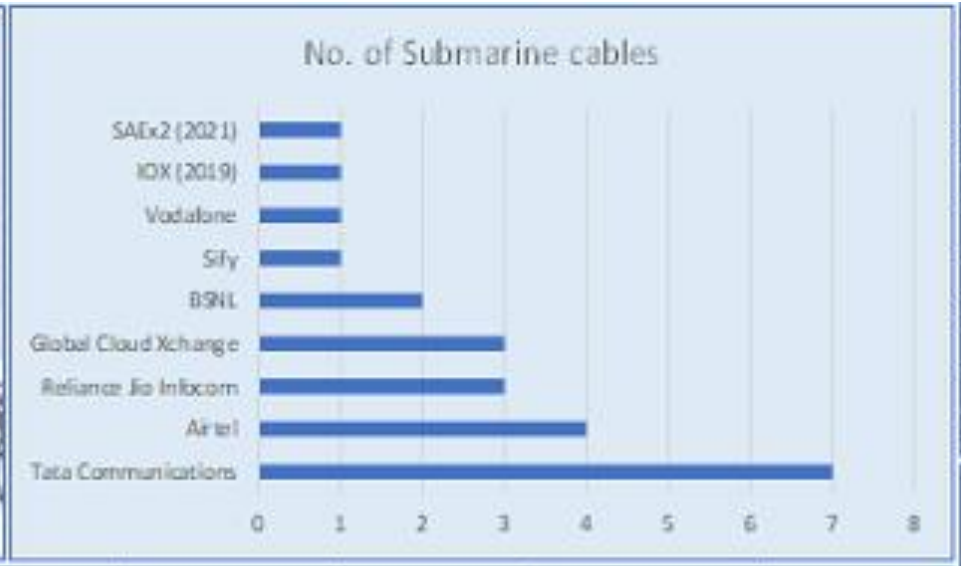




- The Chennai - Andaman and Nicobar Islands.
- Length: 2300km, Capacity: 6.4Tbps x 4 (Aug 2020)
- Operators: BSNL(?), Cost: 1224 Cr.
- CLS: (9), Handled by: NEC Corp. (Japan)

# Cable Landing Stations in India






| Mumbai | Chennai | Trivendrum | Tuticorine | Puduchery |
|---|---|---|---|---|
| IMEWE | TIC | WARF | BLCS | IOX |
| TGN-EA/SEACOM | i2i CN | SAFE | | |
| SMW4 | SMW4 | | | |
| BBG | BBG | | | |
| EIG | | | | |
| SMW3 | | | | |
| FLAG Europe-Asia | | | | |
| AAE-1 | | | | |
| FALCON | | | | |
| GBIC/MENA | | | | |

| Tata Communications | Airtel | Global Cloud Exchange | Reliance Jio | BSNL | Vodafone | Sify | IOX |
|---|---|---|---|---|---|---|---|
| IMEWE | IMEWE | FLAG EA | BBG | BLCS | BBG | GBIC/MENA** | IOX (2019) |
| SMW4 | SMW4 | FALCON | AAE-1 | CACS (2019) | | | |
| SMW3 | EIG | WARF | i2i CN* | | | | |
| FLAG | i2i CN | | | | | | |
| TGN-EA/Seacom | GBIC/MENA | | | | | | |
| SAFE | | | | | | | |
| TIC | | | | | | | |

GCX: Reliance Globalcom B.V.
IOX: India Ocean eXchange

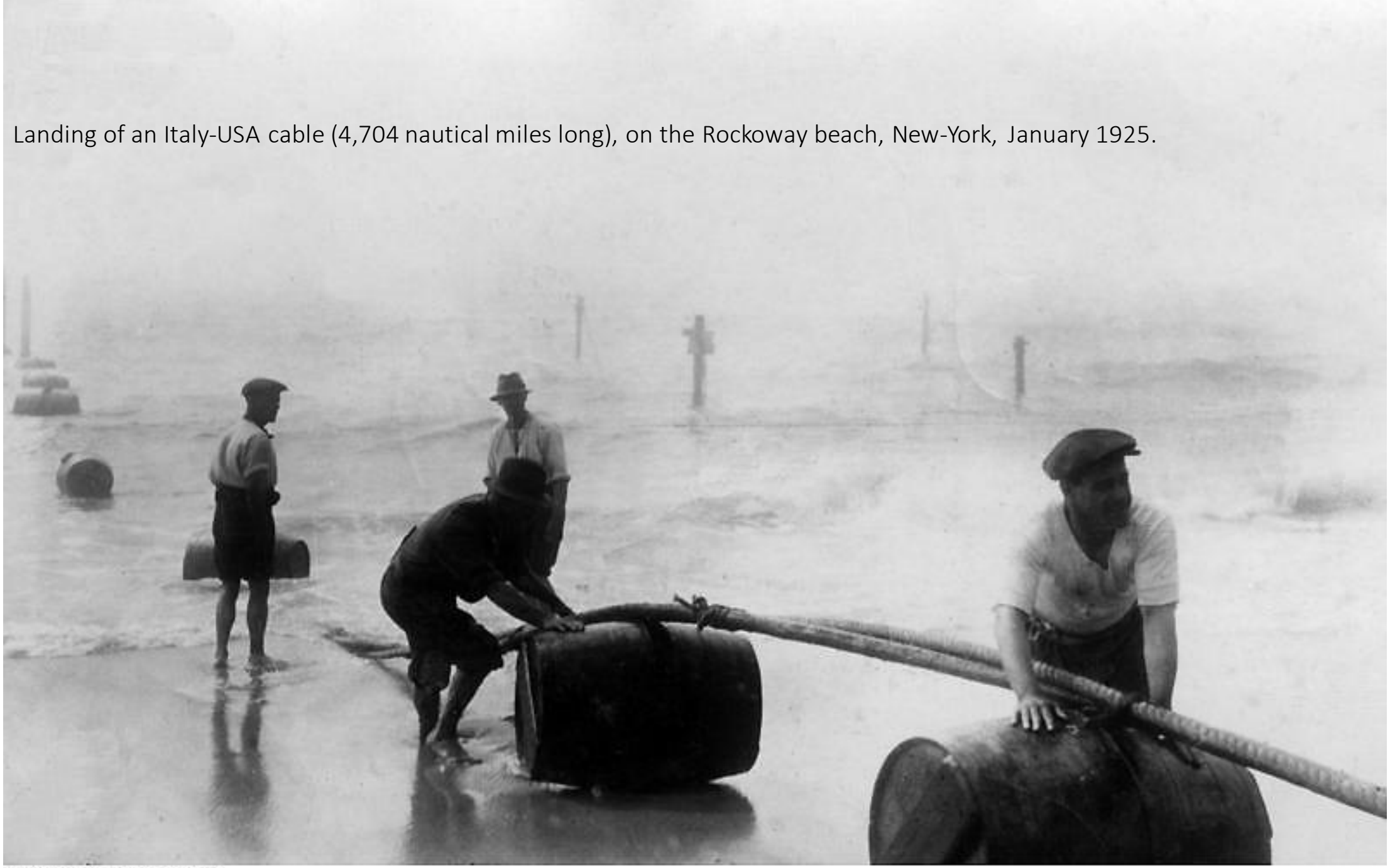
** Only Fiber Pair, ** Only CLS*

| Distribution of Cable Landing Stations and providers that own them | Mumbai | Chennai | Cochin | Trivandrum | Tuticorine | Puduchery | Digha | Visakhapatnam |
|---|---|---|---|---|---|---|---|---|
| Tata Communications | 3 | 1 | 1 | | | | | |
| Airtel | 1 | 2 | | | | | | |
| Reliance Jio | 1 | 1 | | | | | | 1 |
| Global Cloud Xchange | 1 | | | 1 | | | | |
| Vodafone | 1 | | | | | | | |
| Sify | 1 | | | | | | | |
| BSNL | | | | | 1 | | 1 | |
| IOX | | | | | | 1 | | |

CLS Operational | CLS Under Construction

| S No. | Submarine Cable System | Landing City | Landing Party | RFS | Length (kms) | No. of Fiber Pair | No. of Consortium Members |
|---|---|---|---|---|---|---|---|
| 1 | FLAG EA | Mumbai | GCX | 1997 | 28,000 | Two-fiber-pair | 1 |
| 2 | SMW3 | Mumbai, Cochin | TCL | 1999 | 39,000 | Two-fiber-pair | 54 |
| 3 | SAFE | Cochin | TCL | 2002 | 13,500 | Two-fiber-pair | 29 |
| 4 | i2i | Chennai | Airtel | 2002 | 3,200 | Eight-fiber-pair | 1 |
| 5 | TIC | Chennai | TCL | 2004 | 3,175 | Six-fiber-pair | 1 |
| 6 | SMW4 | Mumbai, Chennai | TCL, Airtel | 2005 | 20,000 | Two-fiber-pair | 16 |
| 7 | BLCS | Tuticorin | BSNL | 2006 | 325 | Two-fiber-pair | 2 |
| 8 | FALCON | Mumbai | GCX | 2006 | 10,300 | Six-fiber-pair | 1 |
| 9 | WARF | Cochin | GCX | 2007 | 680 | Two-fiber-pair | 3 |
| 10 | IMEWE | Mumbai | TCL, Airtel | 2010 | 12,091 | Three-fiber-pair | 9 |
| 11 | TGN-EA/SEACOM | Mumbai | TCL | 2011 | 9,280 | Two-fiber-pair | 1 |
| 12 | EIG | Mumbai | Airtel | 2011 | 15,000 | Four-fiber-pair | 16 |
| 13 | GBIC/MENA | Mumbai | Sify | 2012 | 1,500 | Four-fiber-pair | 1 |
| 14 | BBG | Mumbai, Chennai | Jio, Vodafone | 2016 | 8,100 | Three-fiber-pair | 10 |
| 15 | AAE-1 | Mumbai | Jio | 2017 | 25,000 | Five-fiber-pair | 19 |
| 16 | CACN | Chennai | BSNL | 2019 | 2,300 | Four-fiber-pair | 1 |
| 17 | IOX | Puduchery | IOX | 2019 | 8,850 | Four-fiber-pair | 1 |
| 18 | SAEx2 | Chennai | SAEX | 2021 | 13,900 | Six-fiber-pair | 1 |
| 19 | Jio New Cable | Mumbai, Chennai | Jio | 2022 | 8,000 | Twelve-fiber-pair | 2/3/4(!) |
| 20 | IIP New Cable | Mumbai, Chennai | IIP | 2022 | 10,000 | 12/16/32 fiber-pair | 3/4 (!) |

Landing of an Italy-USA cable (4,704 nautical miles long), on the Rockoway beach, New-York, January 1925.

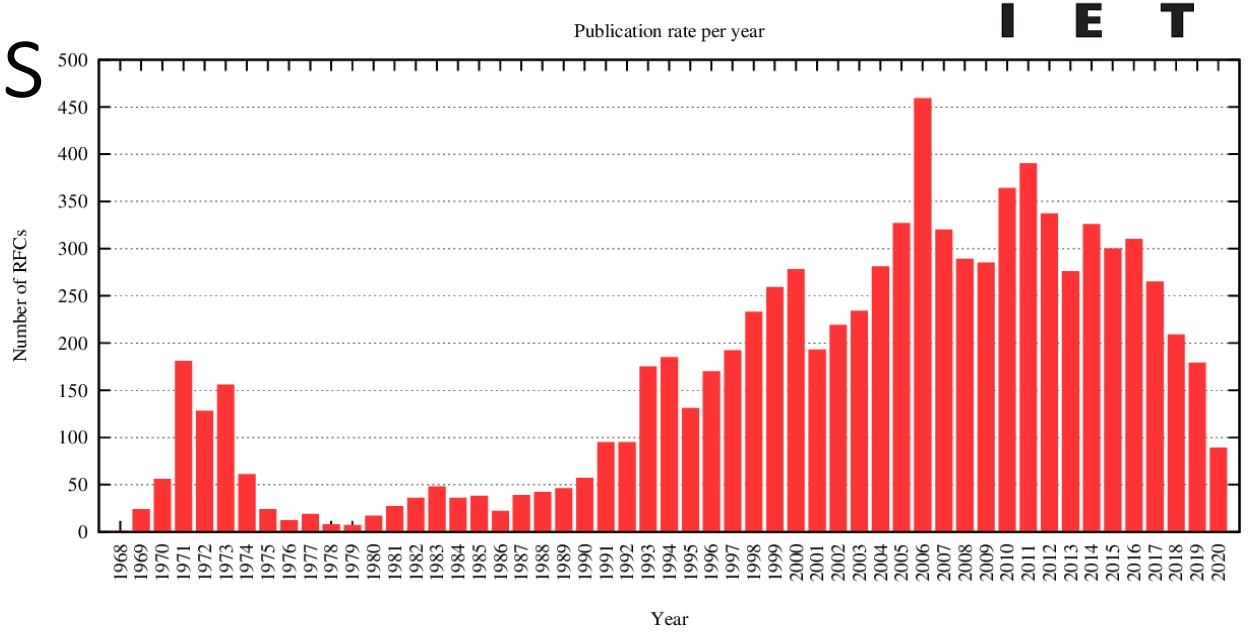


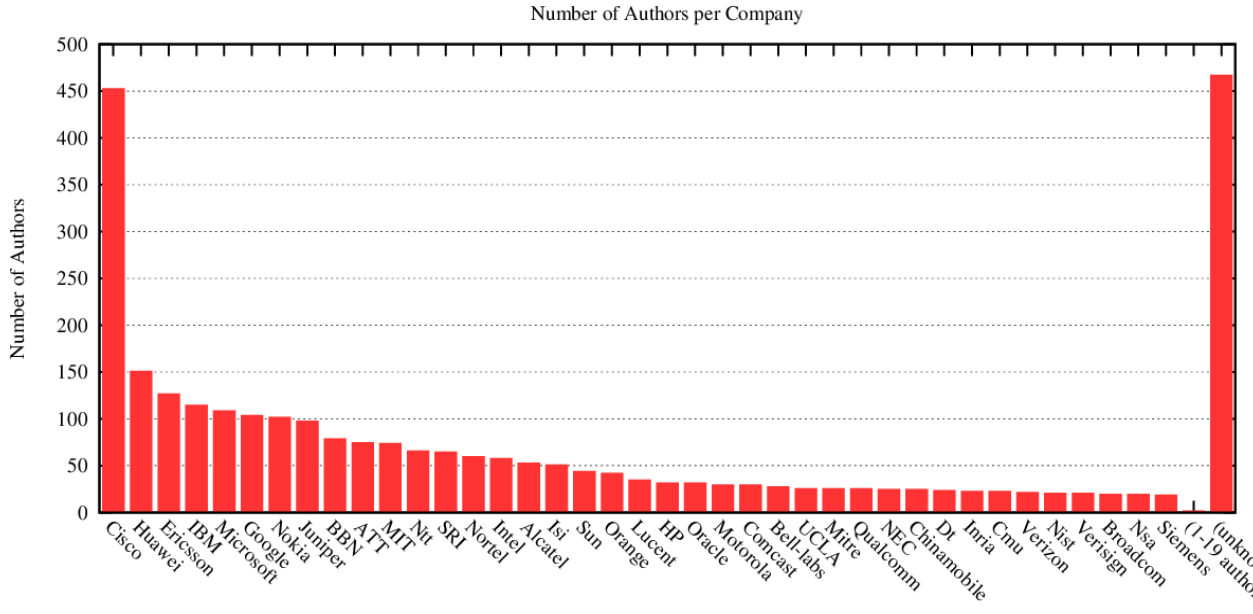
Bundesarchiv, Bild 102-01035
Foto: o.Ang. | 1925 Anfang

# Request For Comments

- RFCs cover many aspects of computer networking, including protocols, procedures, programs, and concepts, as well as meeting notes, opinions, and sometimes humor.
- RFCs area associated with an active IETF Working Group.
- Published RFCs never change. Technical & Editorial Errata are provided.
- Started 7 Apr 1969, by Steve Crocker

- **RFC 1**: Host Software
- **RFC 2555**: 30 Years of RFCs

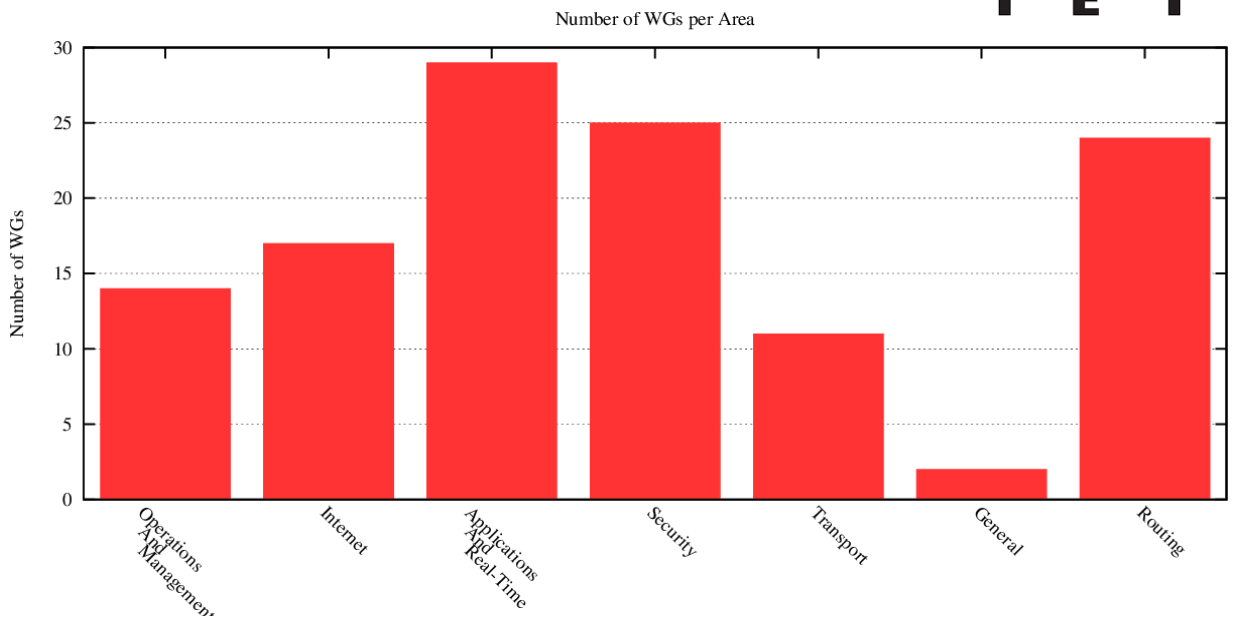


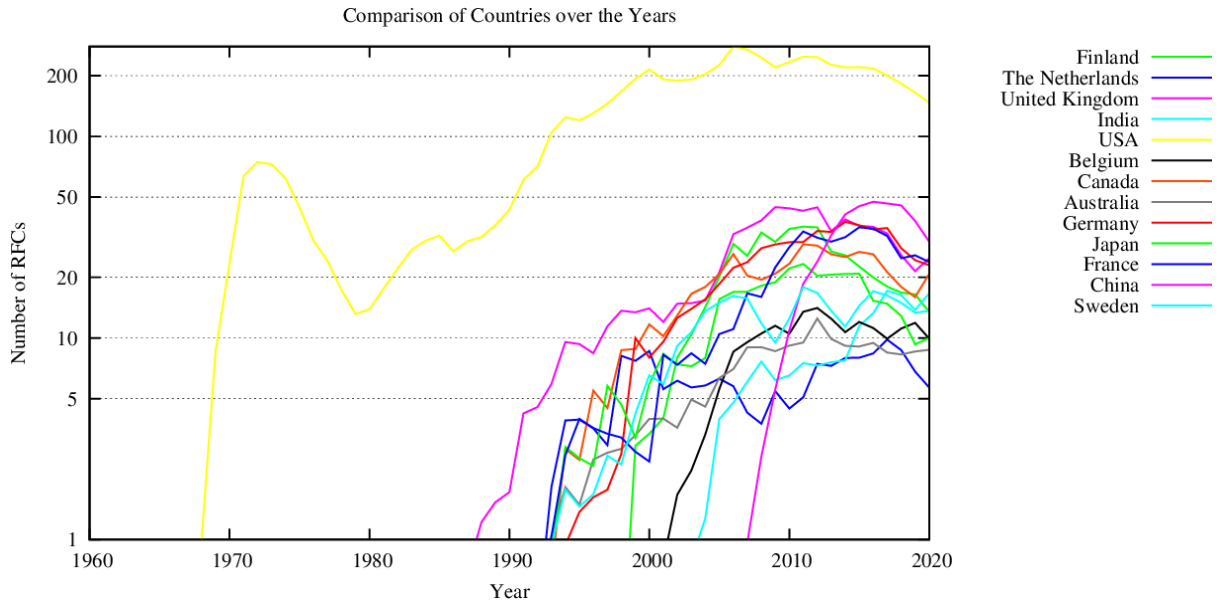




https://ietf.org/standards/rfcs/
www.arkko.com/tools/rfcstats/

# IETF Working Groups

- Applications & Real-Time area (29)
- General area (2)
- Internet area (17)
- Operations & Management area (14)
- Routing area (24)
- Secutiry area (25)
- Transport area (11)




https://ietf.org/standards/rfcs/
https://datatracker.ietf.org/wg/
www.arkko.com/tools/rfcstats/

# April RFCs

- **RFC527: ARPAWOCKY (1973)**
  Beware the ARPANET, my son;
  The bits that byte, the heads that scratch;
  Beware the NCP, and shun
  the frumious system patch,
- **RFC7511: Scenic Routing for IPv6 (2015)**
  This document specifies a new routing scheme for the current version of the Internet Protocol version 6 (IPv6) in the spirit of "Green IT", whereby packets will be routed to get as much fresh-air time as possible.
- **RFC2549: IP over Avian Carriers with Quality of Service (1999)**
  The following quality of service levels are available: Concorde, First, Business, and Coach. Concorde class offers expedited data delivery. One major benefit to using Avian Carriers is that this is the only networking technology that earns frequent flyer miles, plus the Concorde and First classes of service earn 50% bonus miles per packet. Ostriches are an alternate carrier that have much greater bulk transfer capability but provide slower delivery, and require the use of bridges between domains.

IPoAC: IP over Avian Carriers

RFC 3514 The Security Flag in the IPv4 Header 1 April 2003

The bit field is laid out as follows:

```
 0
+-+
|E|
+-+
```

Currently-assigned values are defined as follows:

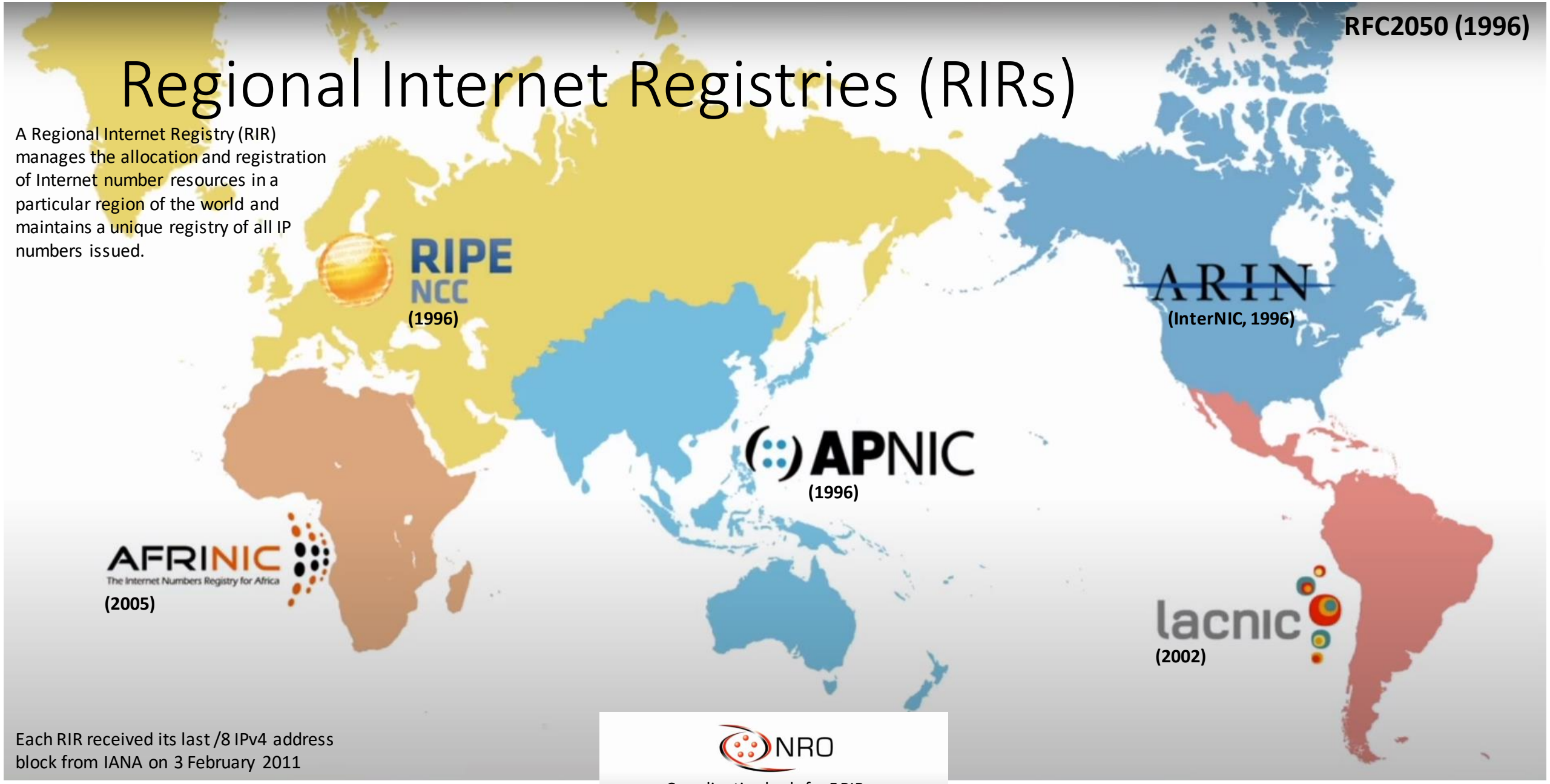
0x0 If the bit is set to 0, the packet has no evil intent. Hosts, network elements, etc., SHOULD assume that the packet is harmless, and SHOULD NOT take any defensive measures. (We note that this part of the spec is already implemented by many common desktop operating systems.)

0x1 If the bit is set to 1, the packet has evil intent. Secure systems SHOULD try to defend themselves against such packets. Insecure systems MAY chose to crash, be penetrated, etc.

# Regional Internet Registries (RIRs)

**RFC2050 (1996)**

A Regional Internet Registry (RIR) manages the allocation and registration of Internet number resources in a particular region of the world and maintains a unique registry of all IP numbers issued.



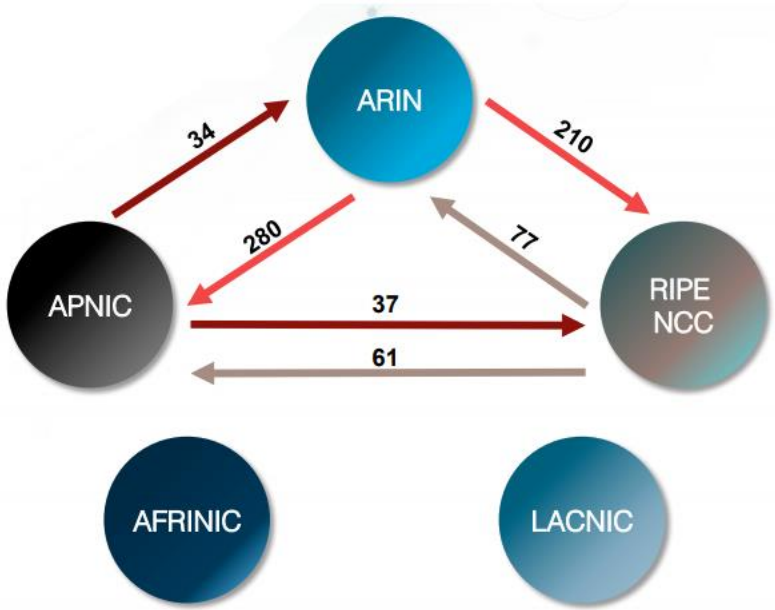

Each RIR received its last /8 IPv4 address block from IANA on 3 February 2011

NRO

Coordinating body for 5 RIRs

**Number Resource Organization**

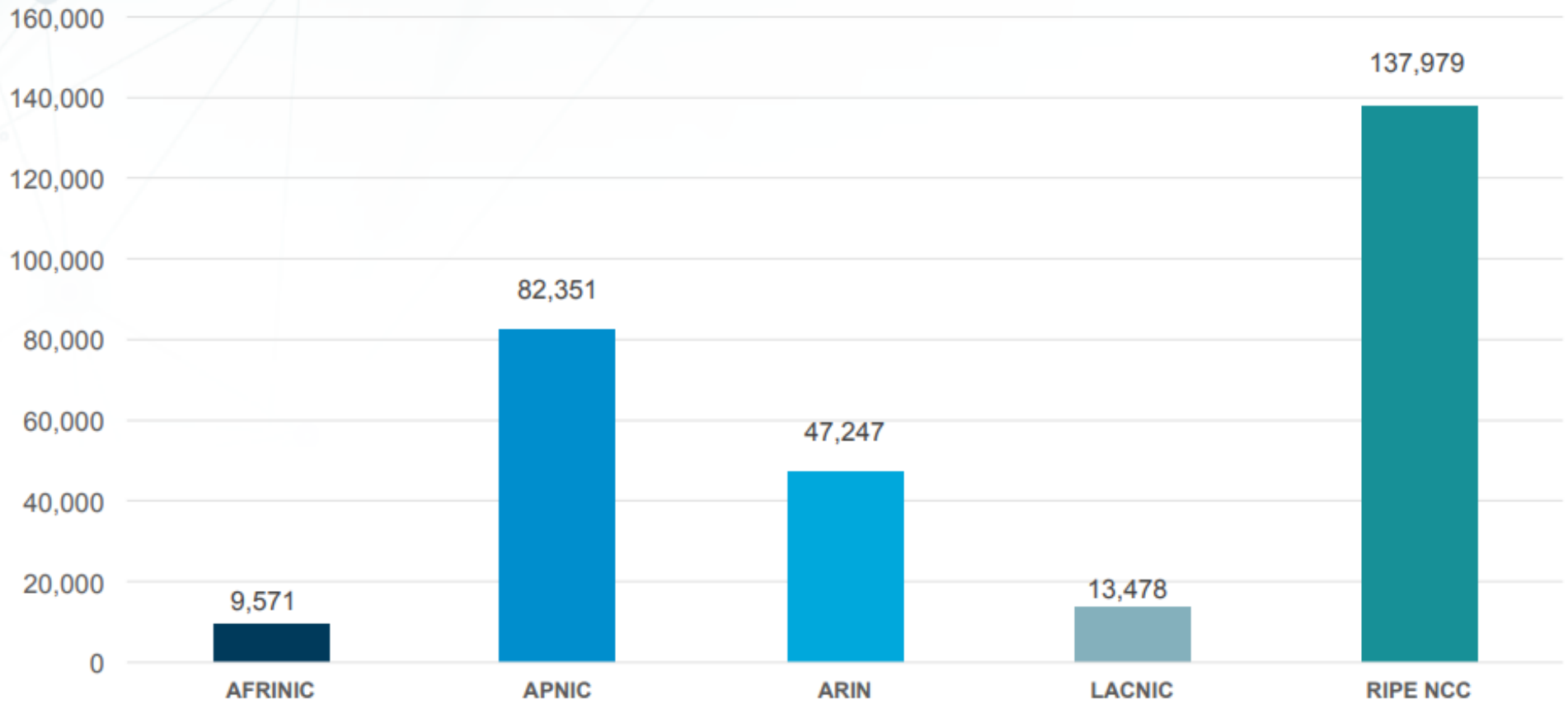
# National Internet Registries (RIRs)

ICANN | ASO
Address Supporting Organization

# Total IPv6 Space Currently Allocated

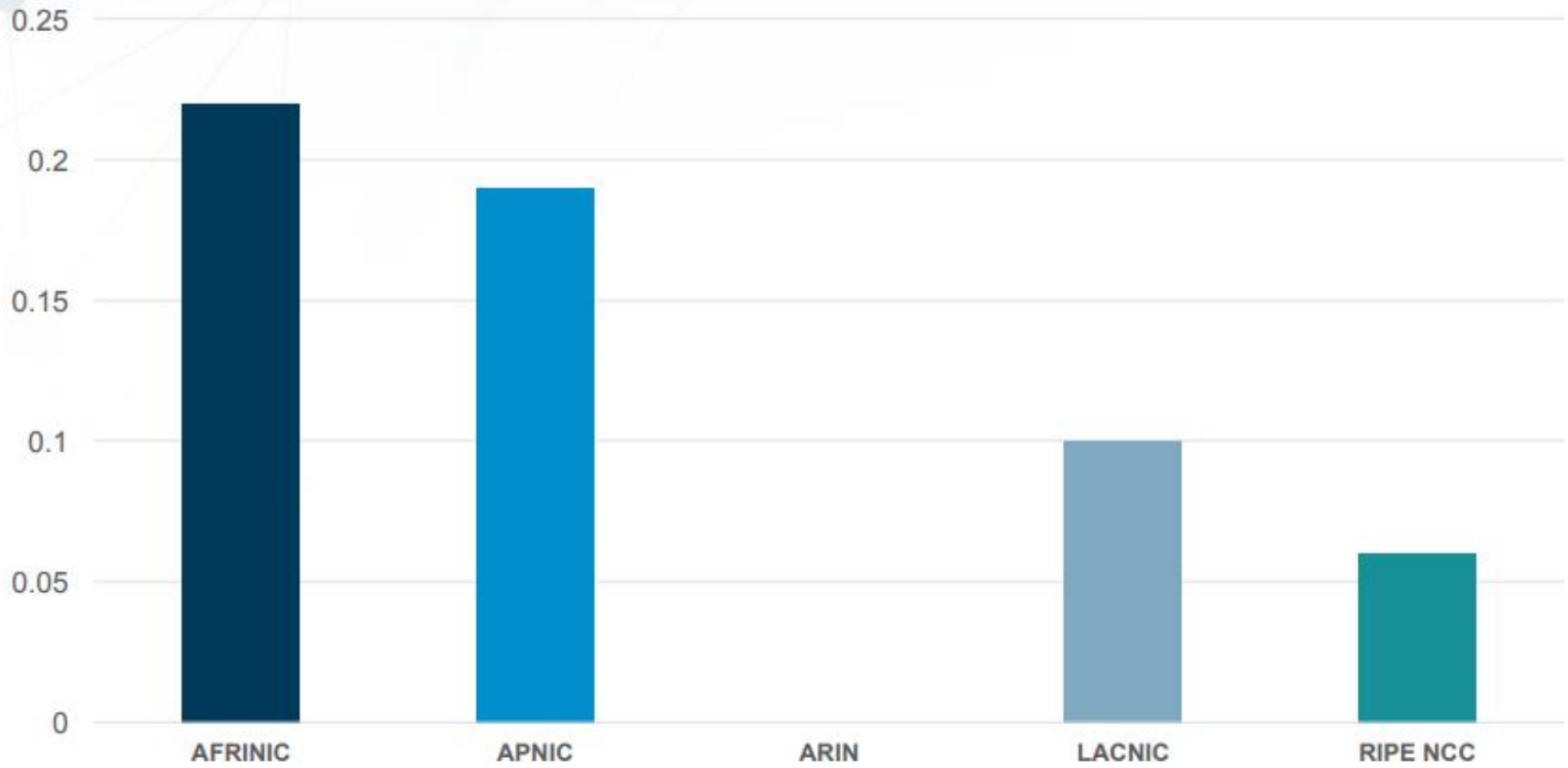
- **Total IPv6 space (in /32s) each RIR has allocated**



ICANN | ASO
Address Supporting Organization

# IPv4 Space Currently Available in Each RIR

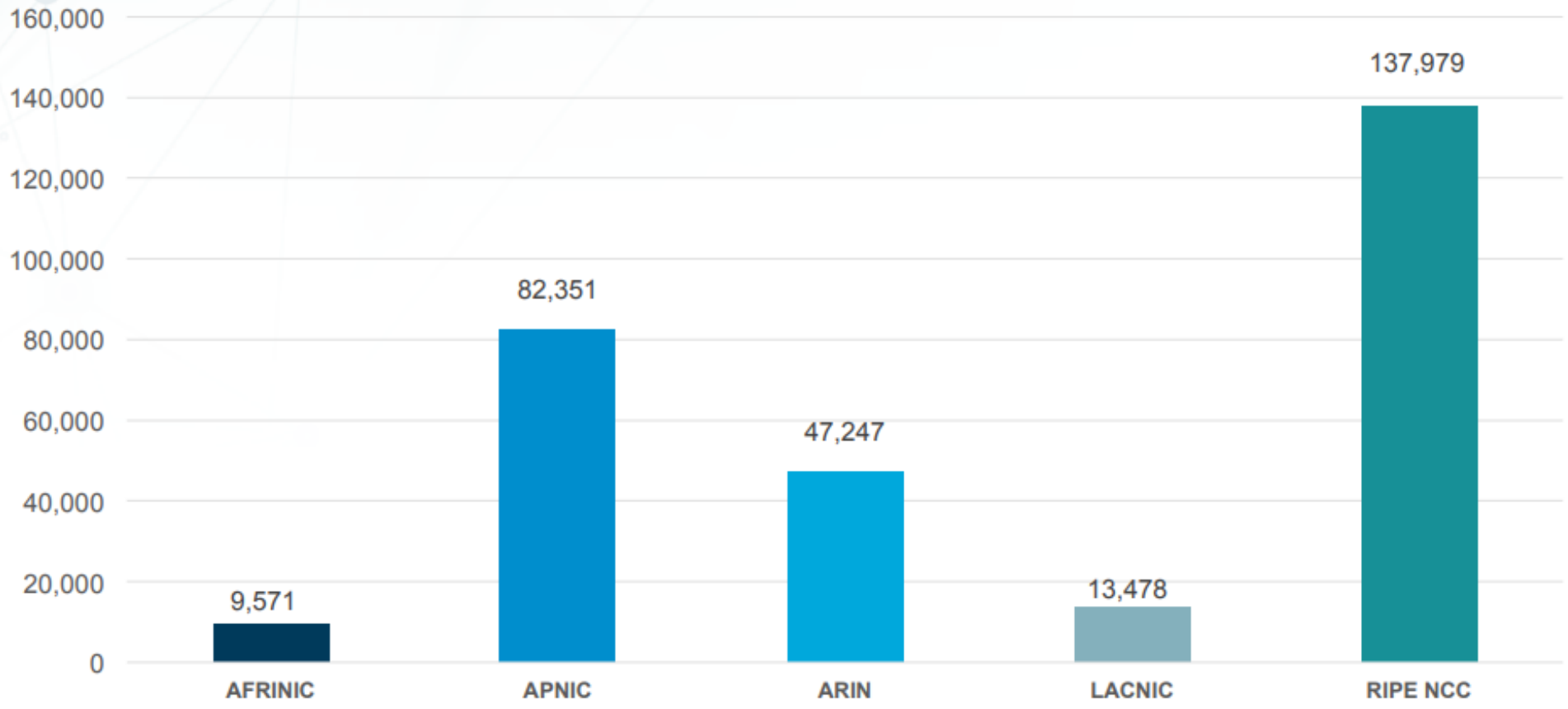
- Measured in /8s



ICANN | ASO
Address Supporting Organization

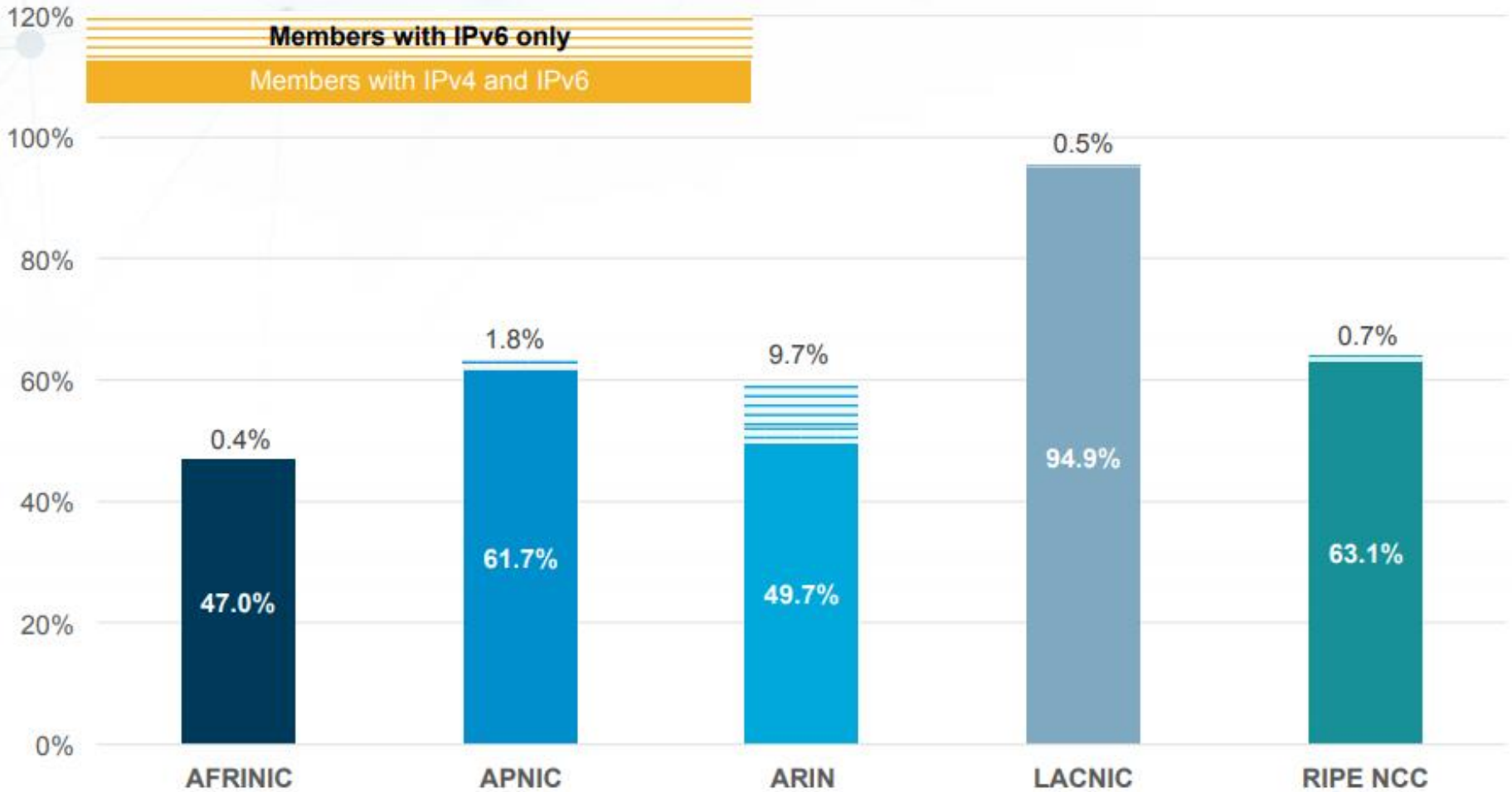
# Total IPv6 Space Currently Allocated

- **Total IPv6 space (in /32s) each RIR has allocated**



ICANN | ASO
Address Supporting Organization

# Percentage of Members with IPv6



# 1993

M: 0 ASN: 0 IPv4: 405 IPv6: 0 S: 1

The distribution of the registration function is desirable, and in keeping with that goal, it is necessary to develop a plan which manages the distribution of the network number space. The demand for network numbers has grown significantly within the last two years and as a result the allocation of network numbers must be approached in a more systematic fashion. - *RFC1466*

The pentium processor is invented

The World Wide Web is born at CERN

Development of CIDR support in routing protocols underway

Japan has the fastest bandwidth speed in the world, at 2.17 Mbps

# 1994

M: 27 ASN: 1 IPv4: 513 IPv6: 0 S: 2

NETSCAPE

Netscape releases the Navigator browser in October under the code name Mozilla

In late 1994 SSL encryption is introduced to make transactions secure

CIDR and BGP4 deployment by major network operators across the Internet

APCCIRN becomes the Asia Pacific Networking Group (APNG)

eCommerce arrives on the Internet:

- Pizza Hut offers online ordering
- The first online bank opens
- There are attempts to offer flower delivery and magazine subscriptions online

# 1995

M: 55 ASN: 47 IPv4: 993 IPv6: 0 S: 3

JAVA

Java computer language invented

DVD

DVD (Digital Versatile Disc or Digital Video Disc) invented

The US Space Shuttle (STS-71) docks to the Mir space station for the first time

Internet users number 16 million, 4% of the population

# 1996

M: 114 ASN: 63 IPv4: 1050 IPv6: 0 S: 5

Internet address space is distributed according to the following three goals:
1) Conservation
2) Routability
3) Registration

Regional Internet Registries (RIRs) operate in large geopolitical regions such as continents. Currently there are three RIRs established; InterNIC serving North America, RIPE NCC serving Europe, and APNIC serving the Asia Pacific region. - RFC2050

Web TV invented

ebaY

Ebay started the online auction and shopping website

# 1997

M: 200 ASN: 98 IPv4:274 IPv6:0 S: 5

APRICOT becomes the Asia Pacific Regional Internet Conference on Operational Technologies and adopts logo designed by Bob Coggeshall.

Singapore became the second country in Asia after Japan to be linked to the global Internet2 infrastructure via the launch of the Singapore Advanced Research and Education Network (SingAREN).

Hong Kong returned to Chinese rule

# 1998

M: 249 ASN: 108 IPv4:166 IPv6:0 S: 6

The BGP table passes 50,000 prefixes for the first time

**Google!**

Google files for incorporation in California on September 4

Apple Computer unveils the iMac

# 1999

M: 396 ASN: 128 IPv4:232 IPv6:5 S: 12

You can create a live journal on LiveJournal.com

**6,000,000,000**

The human population of the world surpasses six billion

# 2000

M: 602 ASN: 230 IPv4:353 IPv6:14 S: 23

2000 Summer Olympics in Sydney, Australia

The billionth living person in India is born

In December, the BGP table passes 100,000 prefixes for the first time

304 million Internet users, 5.0% of the population

# 2001

M: 699 ASN: 220 IPv4:360 IPv6:25 S: 31

Apple's iPod released - would eventually become the most popular portable media player on the market

Wikipedia goes online

The Dotcom Crash wipes billions off the tech stock market

3G network technology becomes available for commercial use first in Japan.

# 2002

M: 767 ASN: 203 IPv4:301 IPv6:86 S: 33

The Euro enters circulation

The world's first cyborg is created

The dwarf planet Quaoar is discovered

# 2003

M: 879 ASN: 198 IPv4:422 IPv6:50 S: 40

Concorde makes its last commercial flight, bringing the era of airliner supersonic travel to a close, at least for the time being

The human genome sequenced

# 2004

M: 978 ASN: 186 IPv4:568 IPv6:57 S: 44

Facebook is launched

Motorola RAZR V3 is released

"Web 2.0" emerges

Measuring 509m (1,671 ft) to the tip of its spire, Taipei 101 becomes the tallest building in the world. It is the first skyscraper to break the half-kilometer mark.

# 2005

M: 1157 ASN: 245 IPv4:705 IPv6:51 S: 46

YouTube - the online video sharing and viewing community - is invented by Steve Chen, Chad Hurley and Jawed Karim. The first YouTube video posted was posted by co-founder Jawed Karim at the San Diego Zoo. It was uploaded on April 23, 2005.

1,018 million internet users, 15.7% of the population

France has the fastest bandwidth at 200,000 Mbs, with China at 136,106 Mbs

# 2006

M: 1362 ASN: 298 IPv4:864 IPv6:42 S: 46

The first tweet was written by co-founder Jack Dorsey on March 21, 2006

The one billionth song is purchased from Apple iTunes

Pluto is demoted to "dwarf planet" status

Google purchases YouTube for US$1.65 billion in stock

# 2007

M: 1584 ASN: 308 IPv4:917 IPv6:63 S: 57

Apple Introduces the iPhone on June 29th

Amazon releases the kindle

Singapore Airlines is the first airline to fly the new Airbus passenger jet A380 on scheduled service between Singapore and Sydney, Australia

By the end of 2007, ecommerce sales accounted for 3.4 percent of total retail sales.

# 2008

M: 1855 ASN: 418 IPv4:984 IPv6:160 S: 62

The Large Hadron Collider (LHC), the world's largest and highest-energy particle accelerator, is considered "one of the great engineering milestones of mankind". Built by the European Organization for Nuclear Research (CERN)

In March, the BGP table passes 250,000 prefixes for the first time

Internet access is disrupted in the Middle East and India due to breaks in submarine cable systems in the Mediterranean

By 2008 Google had processed over 1,000,000,000,000 (one trillion) unique URLs, while the number of individual web pages was growing by several billion per day and the number of individual users had reached nearly 1.5 billion

# 2009

M: 2170 ASN: 436 IPv4: 1065 IPv6: 185 S: 63

Scientists engineer new plastics without the use of fossil fuels

The mouse genome is sequenced

3D scanning enters the consumer market

The first exoplanet that could contain liquid water is discovered

Sina Weibo is established

# 2010

M: 2521 ASN: 505 IPv4: 1358 IPv6: 643 S: 65

Apple debuts the iPad

Scientists create synthetic life

Scientists trap antimatter

Speech-to-speech translation is common in mobile phones

1,966 million Internet users, 28.7% of the population

# 2011

M: 2947 ASN: 495 IPv4: 1475 IPv6: 620 S: 70

Each RIR received its last /8 IPv4 address block from IANA on 3 February 2011

The world's first synthetic transplant occurs

**7,000,000,000**

Global population reaches 7 billion

Multi-touch surface computing enters the consumer market

Estimated total online retail sales of merchandise during 2011 at $188.1 billion

# 2012

M: 3534 ASN: 581 IPv4: 1075 IPv6: 562 S: 71

Twitter reaches the half billion accounts mark in June 2012. Jakarta is the top city by number of Tweets followed by Tokyo and London

2,405 million Internet users, 34.3% of the population

# 2013

M: 3779 ASN: 306 IPv4: 744 IPv6: 255 S: 68

Sina Weibo passes
500 Million users

# 2014

M: 4051 ASN: 646 IPv4: 3914 IPv6: 484 S: 70

40% of world's population with Internet access

3B Internet users; two-thirds of world's Internet users are from developing economies

**3,000,000,000**

Mobile cellular subscriptions reach almost 7B (3.6B in AP region)

# 2015

M: 5268 ASN: 881 IPv4: 4498 IPv6: 785 S: 76

42.4% of world's population with Internet

3.2B Internet users

**3,200,000,000**

7B+ mobile cellular subscriptions

# 2016

M: 5994 ASN: 881 IPv4: 4498 IPv6: 785 S: 75

47% of world's population with Internet

3.4B Internet users

**3,400,000,000**

# 2017

M: 6557 ASN: 1226 IPv4: 2235 IPv6: 1377 S: 77

50% of world's population with Internet

3.8B Internet users worldwide

**3,800,000,000**

4.9B unique mobile users worldwide; 3.9B mobile subscriptions in the Asia Pacific

# 2018

M: 7162 ASN: 912 IPv4: 2199 IPv6: 1430 S: 80

IPv6 adoption increased, with the proportion of Members holding IPv6 resources reaching 61% and total IPv6 capability reaching 22%

Blockchain technology is invented to protect cryptocurrency transactions

5G

5G, the fifth generation of wireless technology is developed. It promises speeds in excess of 1Gbps

# 2019

M: 7776 ASN: 1560 IPv4: 2027 IPv6: 1472 S: 77

IBM announces the first commercial quantum computer, the IBM Q System One