# Use of the satellite in the global infrastructures

## Architectural issues

# ITU *integration* levels*

- Geographical
  - Satellite provides service only in areas not covered by terrestrial networks; services and technologies can be different.
- Services
  - Implies geographical integration and compatibility among services provided by the two networks; performance can be different.
- Network
  - Same procedures and protocols allowing to dial the same number independently on the used terminal; different carrier frequency eventually utilized by the two segments must be taken into account.
- Equipment
  - Compatibility in terms of access, protocols, data rate so that at least a part of the circuits could be shared.
- System
  - Maximum level; users are not aware of what kind of connection has been established.

* Very old ITU recommendation referred to just telephone service

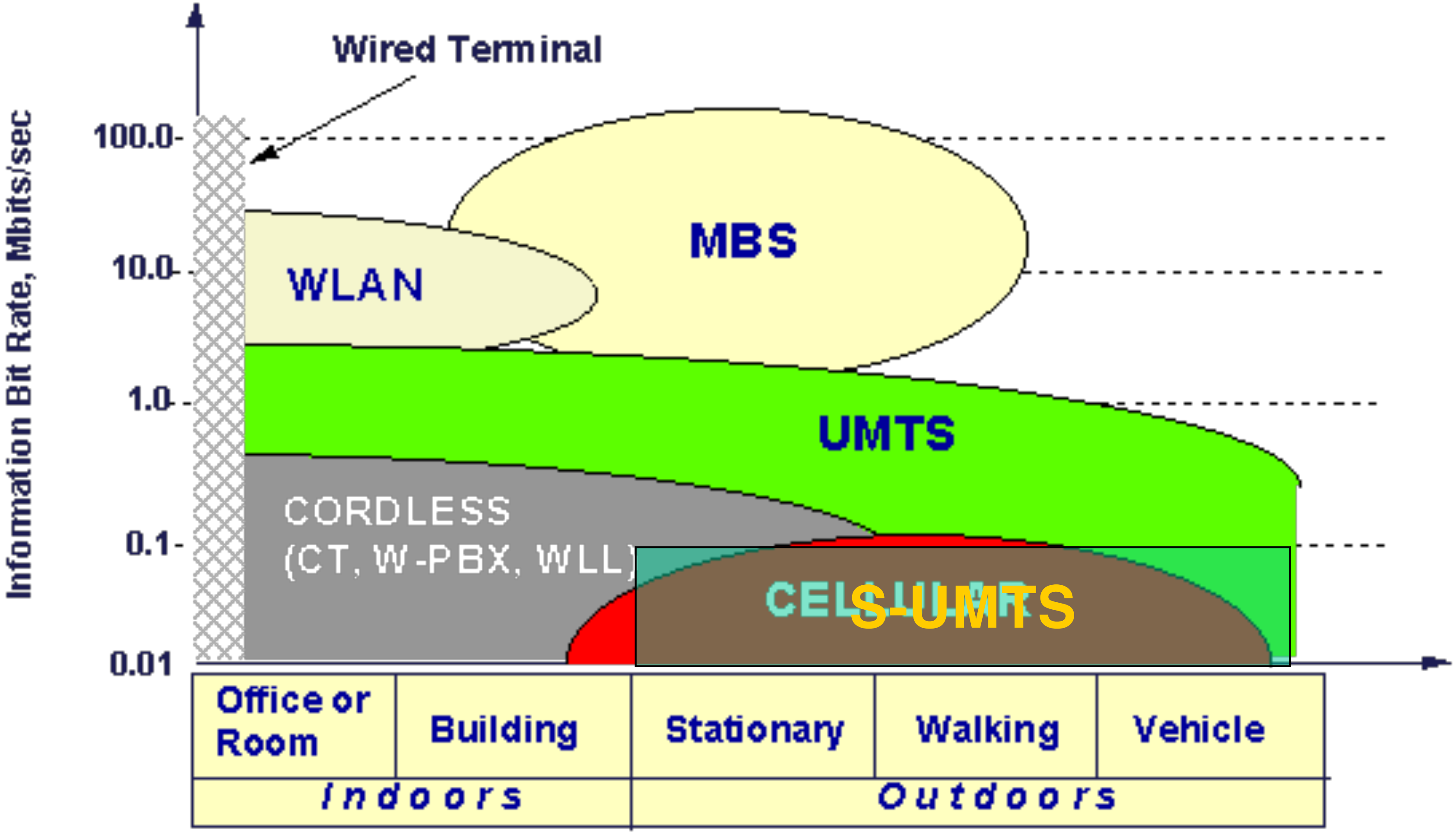
# Basic concepts

- Satellite systems and terrestrial systems can be:
  - Interconnected (only physical layer involved to provide basic services)
  - Cooperating (exchange of information to allow service exploitation)
  - Interworking (protocol adaptation to guarantee exploitation of particular service requirements)
  - Interoperable (different standards are reciprocally compliant)
  - Integrated (they belong to the same systems)
  - Components of the same slice (5G)
- Interconnection with fixed terrestrial networks realized through gateways

# History: S-UMTS

- Satellite component of UMTS
- The first time satellite considered an integral part of a cellular global communication networks
- Intersegment handover with the terrestrial segment
- Dual mode user terminals (easier with adjacent frequency bands)
- Common UMTS core network
- Aims at:
  - Complementing terrestrial system coverage supporting a subset of services
  - Ensuring global coverage and roaming
  - Supporting up to 144 kbit/s bit rate

# UMTS


Wired Terminal
Information Bit Rate, Mbits/sec
100.0
10.0
1.0
0.1
0.01
MBS
WLAN
UMTS
CORDLESS
(CT, W-PBX, WLL)
S-UMTS
Office or Room
Building
Stationary
Walking
Vehicle
Indoors
Outdoors

# UMTS Scenario

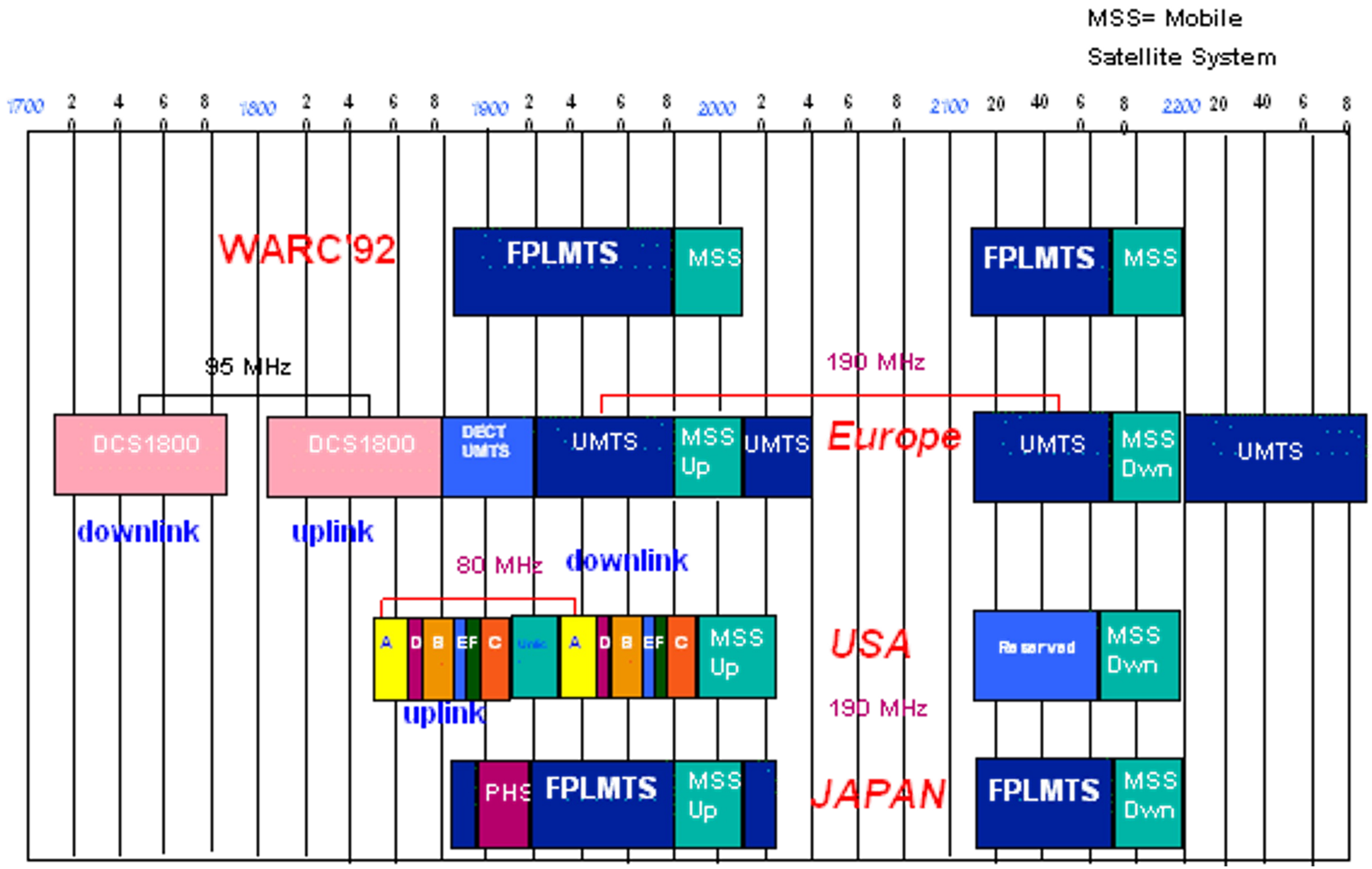
# S-UMTS Terminals

- Type H: Handheld portable terminal
- Type V: Vehicular terminal
- Type T: Transportable terminal
- Type F: Fixed terminal
- Type P: Satellite pager
  - Handheld terminal1 (types H and P)
    - Antenna gain = 0 dB
    - Maximum RF power: 50 mW
    - 50 % voice activation
  - Portable terminal1 (types V,T and F)
    - Antenna gain = 2 dB for LEO and ICO constellations (V,T)
    - Antenna gain = 11 dB for GEO satellites (F)
    - Maximum RF power=8 W (V,T) and (F)445

# S-UMTS Services

| ***Teleservice*** | ***Urban*** | ***Rural*** | ***Indoor*** | ***Bit rate*** | ***B.E.R*** |
|---|---|---|---|---|---|
| **Telephony** | | | | | |
| Speech | H, V, T | H, V, T | | 4-32 | $10^{-3}$<br>$10^{-4}$ |
| Emergency Call | H, V, T | H, V, T | | 4-32 | $10^{-3}$<br>$10^{-4}$ |
| Teleconference | H, V, T | H, V, T | | 16-56<br>32-128 | $10^{-5}$<br>$10^{-4}$ |
| **Voice Band Data** | | | | | |
| Facsimile | H, V, T | H, V, T | | 32-40<br>32-64 | $10^{-5}$<br>$10^{-6}$ |
| Modems | H, V, T | H, V, T | | 12-40<br>32-64 | $10^{-6}$<br>$10^{-6}$ |
| Data terminal | H, V, T | H, V, T | | 2.4-36<br>2.4-64 | $10^{-6}$<br>$10^{-6}$ |
| voice | H, V, T | H, V, T | | | |
| **Sound** | | | | | |
| Program Sound | H, V, T | H, V, T | | 128 | $10^{-6}$ |
| High Quality Audio | H, V, T | H, V, T | | 940 | $10^{-5}$ |
| Video Telephony | H, V, T | H, V, T | | 12-40<br>32-64 | $10^{-5}$<br>$10^{-6}$ |
| Video Conference | H, V, T | H, V, T | | 384-768 | $10^{-7}$ |
| Video Surveillance/ monitoring | H, V, T | H, V, T | | | |
| **Messaging** | | | | | |
| SMS + Paging | H, V, T, P | H, V, T, P | H, V, T, P | 1.2-9.6 | $10^{-6}$ |
| Voice Mail | H, V, T | H, V, T | | 4-32<br>4-32 | $10^{-3}$<br>$10^{-4}$ |
| Fax Mail/St. & F | H, V, T | H, V, T | | | |
| Video Mail | H, V, T | H, V, T | | | |
| Elect. Mail | H, V, T | H, V, T | | 1.2-64<br>1.2-64 | $10^{-5}$<br>$10^{-6}$ |
| Telefax (g4) | H, V, T | H, V, T | | 32<br>64 | $10^{-5}$<br>$10^{-6}$ |
| Broadcast services | H, V, T, P | H, V, T, P | H, V, T, P | 1.2-9.6 | $10^{-6}$ |
| Unrestricted Digital/Information | H, V, T | H, V, T | | | |
| Data Base access | H, V, T | H, V, T | | 1.2-40<br>2.4-768 | $10^{-5}$<br>$10^{-6}$ |
| Teleshopping | H, V, T | H, V, T | | 1.2-40<br>2.4-768 | $10^{-5}$<br>$10^{-6}$ |
| Electronic Newspaper | H, V, T | H, V, T | | | |
| Location + Navigation | H, V, T | H, V, T | | 32<br>64 | $10^{-5}$<br>$10^{-6}$ |

# Spectrum Allocation



# UMTS Proposed Standards

| RTT Candidate | Description | Environment | | | | Source |
|---|---|---|---|---|---|---|
| | | Indoor | Pedestrian | Vehicular | Satellite | |
| DECT | Digital Enhanced Cordless Telecommunications | X | X | - | - | ETSI |
| UWC-136 | Universal Wireless Communications | X | X | X | - | USA |
| WIMS W-CDMA | Wireless Multimedia & Messaging Services Wideband CDMA | X | X | X | - | USA |
| TD-SCDMA | Time Division Synchronous CDMA | X | X | X | - | China |
| W-CDMA | Wideband CDMA | X | X | X | - | Japan |
| CDMA II | Asynchronous DS-CDMA | X | X | X | - | South Korea |
| UTRA | *UMTS* Terrestrial Radio Access | X | X | X | - | ETSI |
| NA:W-CDMA | North American Wideband CDMA | X | X | X | - | USA |
| CDMA-2000 | Wideband CDMA (IS-95) | X | X | X | - | USA |
| CDMA-1 | Multi-band synchronous DS-CDMA | X | X | X | - | South Korea |
| SAT-CDMA | Satellite-based CDMA system | - | - | - | X | South Korea |
| SW-CDMA | Satellite-based Wideband CDMA | - | - | - | X | European Space Agency |
| SW-CTDMA | Satellite Wideband hybrid CDMA/TDMA | - | - | - | X | European Space Agency |
| ICO RTT | ICO-developed satellite system | - | - | - | X | ICO |
| Horizons | Inmarsat-developed satellite system | - | - | - | X | Inmarsat |

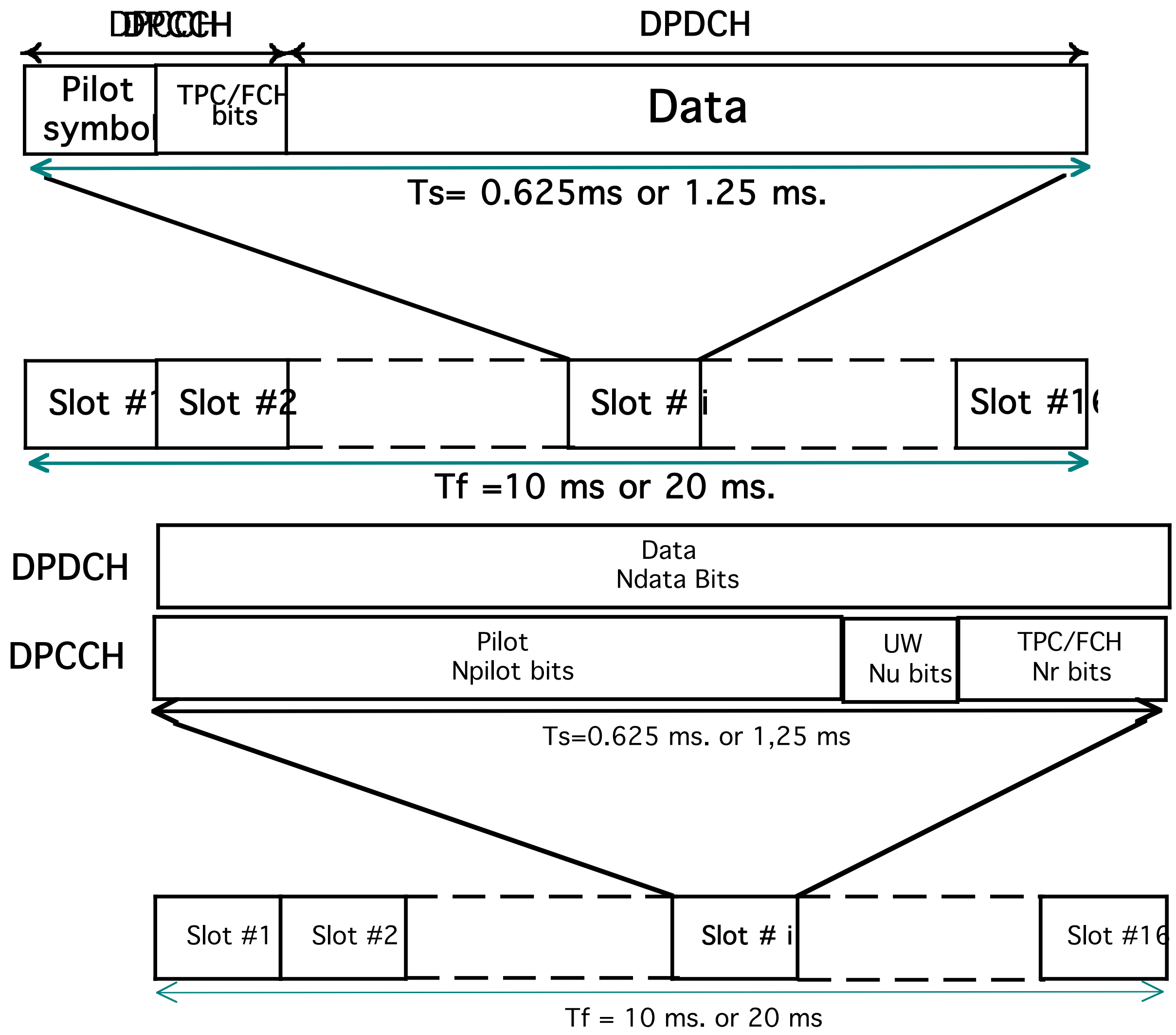
# SW-CDMA description

- Similar to the ETSI UTRA proposal suited to the specific satellite environment
- Main features:
  - Wide range of bearer services (from 2.4 kbit/s up to 144 kbit/s)
  - Power and spectral efficiency through:
    - Path diversity exploitation
    - Coherent demodulation on the return link
    - Multi-user detection scheme
    - Overhead reduction using common pilot/beam approach
    - Compatibility with adaptive antenna systems
  - MS localisation capabilities
- Two chip rate option supported
  - 4.096 Mchip/s (frame duration = 10 ms)
  - 2.048 Mchip/s (frame duration = 20 ms)
- QPSK and Dual-BPSK (for low data rate) modulations
- Physical channels definition:
  - Dedicated Data Channel (DPDCH)
  - Dedicated Control Channel (DPCCH)
  - Transmit Power Control (TCP)
  - Frame Control Header (FCH)
- Single Power Control Command (justified by the large propagation delay)
- Optional use of scrambling code

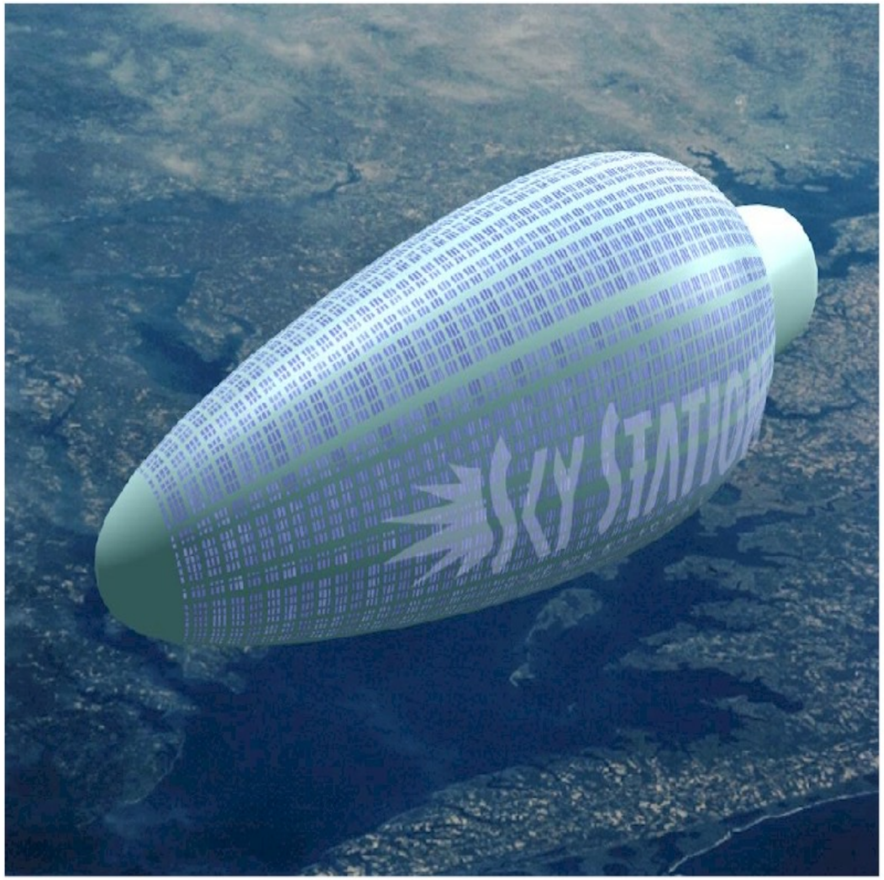
# Frame Structure

Forward link

Return link



# Sky Station


SKY STATION


video phone, email, internet
digital phones
UAC (75 km diameter)
SAC (150 km diameter)
RAC (600 km diameter)

# Sky Station Advantages

- Rapid deployment
- UMTS compatibility (at present no longer important)
- Sky Station platforms do not require a launch vehicle, they can move under their own power throughout the world or remain stationary, and they can be brought down to earth, refurbished and re-deployed.
- Once a platform is in position, it can immediately begin delivering service to its service area without the need to deploy a global infrastructure or constellation of platforms to operate.
- The altitude enables the Sky Station system to provide a higher frequency reuse and thus higher capacity than other wireless systems.
- The low cost of the platform and gateway stations make it the cheapest wireless infrastructure per subscriber conceived to date.
- Each platform can be retrieved, updated, and re-launched without service interruption. Sky Station platforms are environmentally friendly. Powered by solar technology and non-polluting fuel cells.
- Short paths through the atmosphere and unobstructed line-of-sight.

# Disadvantage/Open issues

- Small coverage
- Stability
- Regulation

# Services

- Mobile/portable telephony
- Video telephony
- Videoconference
- High speed Internet access and WWW
- Video on demand
- Surveillance
- Remote sensing

# General characteristics

- Mass 10.5 t, Diameter 62 m, Length 157 m
- 520 kW DC power
- GPS controlled (accuracy few hundred meters)
- Payload mass 1 t
- Up to 130 antennas (7 spot each)
- 15 gateway links.

# Spectrum allocation

- 48/47 GHz (worldwide)
- 31/28 GHz (40 countries)
- 2 GHz (IMT2000 service)

# Telecommunication Service Characteristics

## 47GHz BROADBAND TECHNICAL DETAILS

- Platforms: 250 platforms worldwide, each operating independently and initially connected via ground-stations and existing public networks. Future platforms will be equipped with platform-to-platform links.
- Altitude: 21 km (70,000 feet)
- Coverage Area: 150 km diameter; 19,000 square kilometers plus specified locations outside this zone
- Spot beams: 700 spot beams per platform
- Elevation Angle: >15°
- Life-span: 5-10 years

## SPECTRUM

- – Uplink:100MHz in 47.9 ‹ 48.2 GHz
- – Downlink:100MHz in 47.2 ‹ 47.5 GHz

- Modulation: QPSK (subscriber); 64QAM (ground station)
- Communication protocol: FDMA/TDMA uplink, TDM downlink

## SUBSCRIBER INFORMATION

- Data rate: 2 Mbit/s uplink - 10 Mbit/s downlink
- Power requirements: 100mW - 250mW

# Telecommunication Service Characteristics (2)

## TYPICAL 2 GHZ SKY STATION SYSTEM INFRASTRUCTURE

- Platforms: One platform with several ground stations per metropolitan area
- Altitude: 20-21 km (approx. 70,000 feet)
- Coverage Area: 1000 km diameter footprint
- Spot beams: >1000 spot beams per platform
- Life-span: 5 to 10 years
- Capacity: 1.77 Gbit/s capacity per 10 MHz allocation (5 MHz downlink and 5 MHz uplink) dynamically spread across footprint Equivalent of 316,000 simultaneous 8 kbit/s telephone calls with 50% voice activity

## SPECTRUM

- Frequencies: identified by the WRC for use with Third Generation Mobile Terrestrial Systems. (1885-1980 MHz, 2010-2025 MHz, and 2110-2170 MHz in Regions 1 and 3, and 1885-1980 MHz and 2110-2160 MHz in Region 2).
- Modulation: QPSK
- Multiple access: WCDMA and CDMA2000
- Communication Multiple protocols at transport and network levels protocol: supported

## SUBSCRIBER INFORMATION

- Data rate: 8.0 kbit/s for voice; 384 kbit/s ‹ 2 Mbit/s for data
- Power requirements: 25mW
- Subscriber unit: Standard WCDMA

# Alternative configurations


Fig. 6 Helios. AeroVironment’s craft has a wing span of 75 m and aims to operate up at 100 000 ft under solar power (Photo: NASA Dryden/Tom Tschida)


Fig. 7 HALO Proteus aircraft. Note the pod for the payload underneath. (Courtesy of Angel Technologies Corp.)

Fig. 8 Predator, a military UAV (Courtesy of General Atomics Aeronautical Systems Inc.)

# NICT and SkyNet programme

- Communication and monitoring
- Integrated network of 10 airships to cover Japan

# Stand alone satellite/HAPS characteristics

- Independence on terrestrial facilities
- Suitability for emergency
- Promptness to set up (for the satellite once in orbit)
- Occasional Hot spot capacity provision capability
- Suitability for multicast and broadcast
- Cost-effective provision of telecommunication capabilities
- Flexible architectures
- No real limitations to applications
- ……………………………

**CONCLUSION**

**Are they in competition?**

# Integrated architecture rationale

## With respect to stand alone architectures

### HAPS can help satellites

- To relax user terminal and sat payload requirements
- To use terrestrial like terminals
- To use terrestrial standards
- To enhance coverage in urban areas
- To strongly decrease perceived latency
- To alleviate traffic management handling local traffic

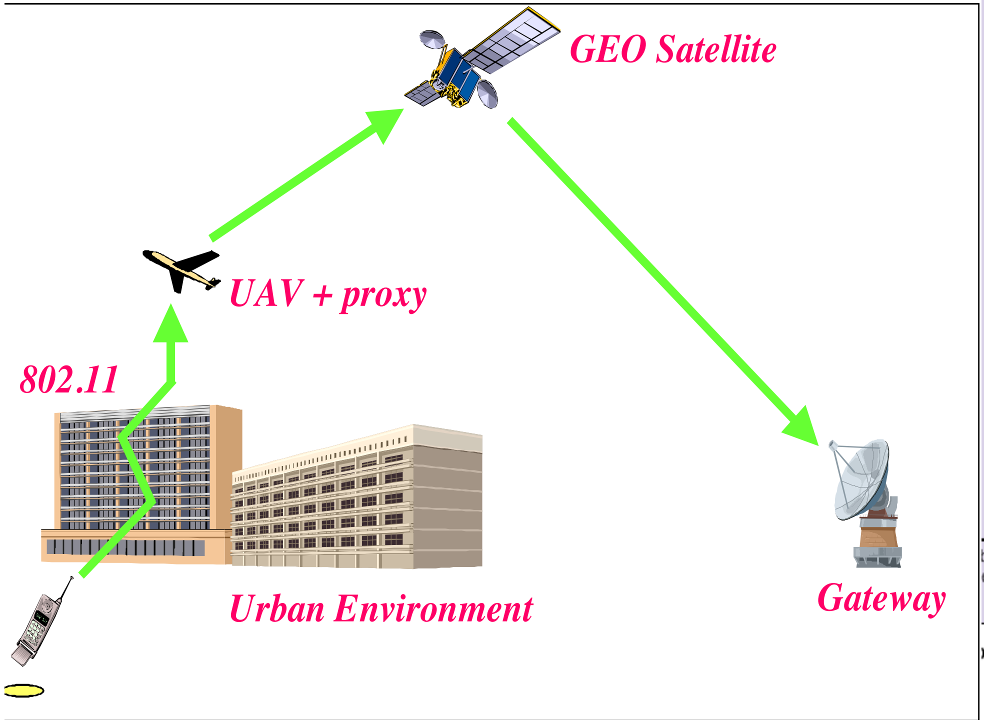
### Satellites can help HAPS

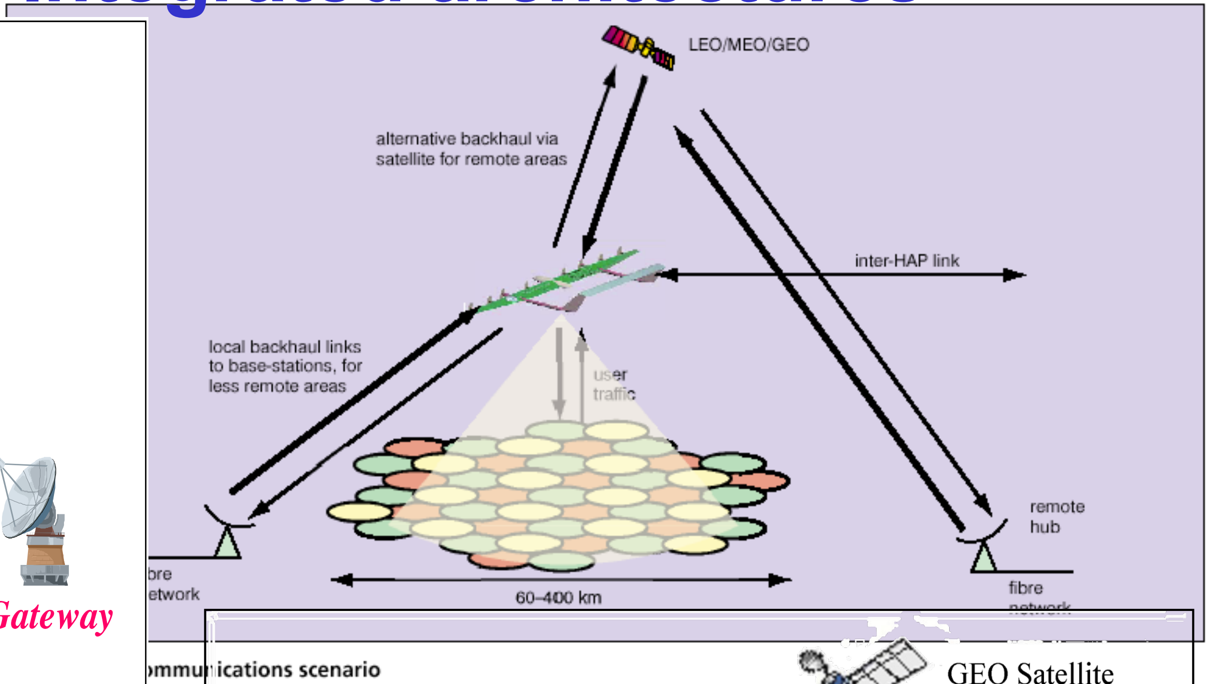
- To extend coverage
- To connect remote locations
- To interconnect haps and clusters
- To connect other networks
- To act as backbone

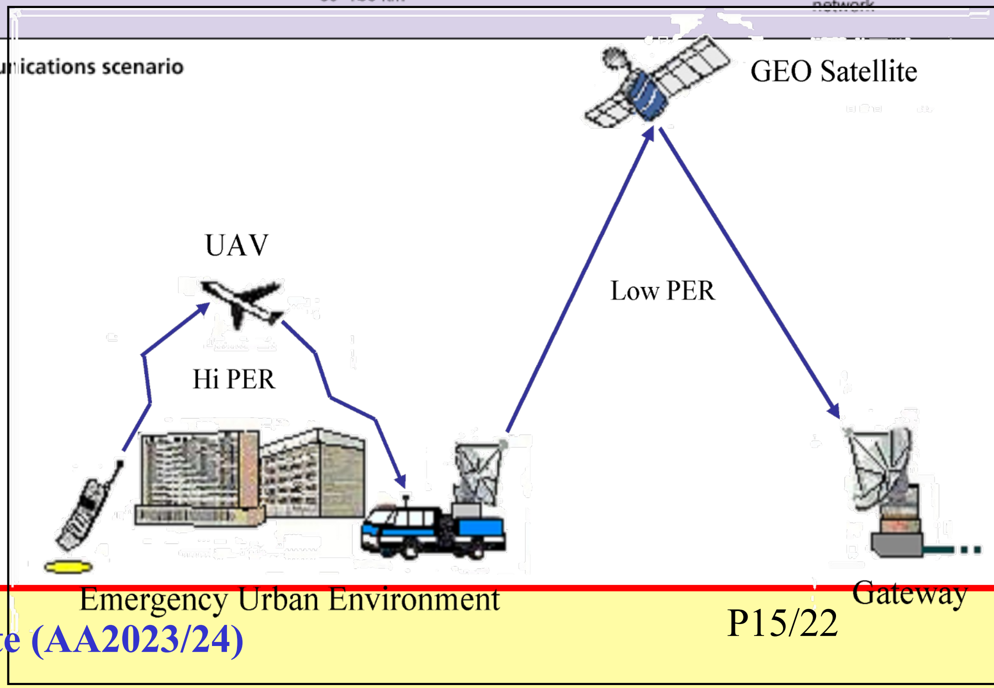
**CONCLUSION**

**Definitively,
they are complementary**

# Satellite HAPS Integrated architectures



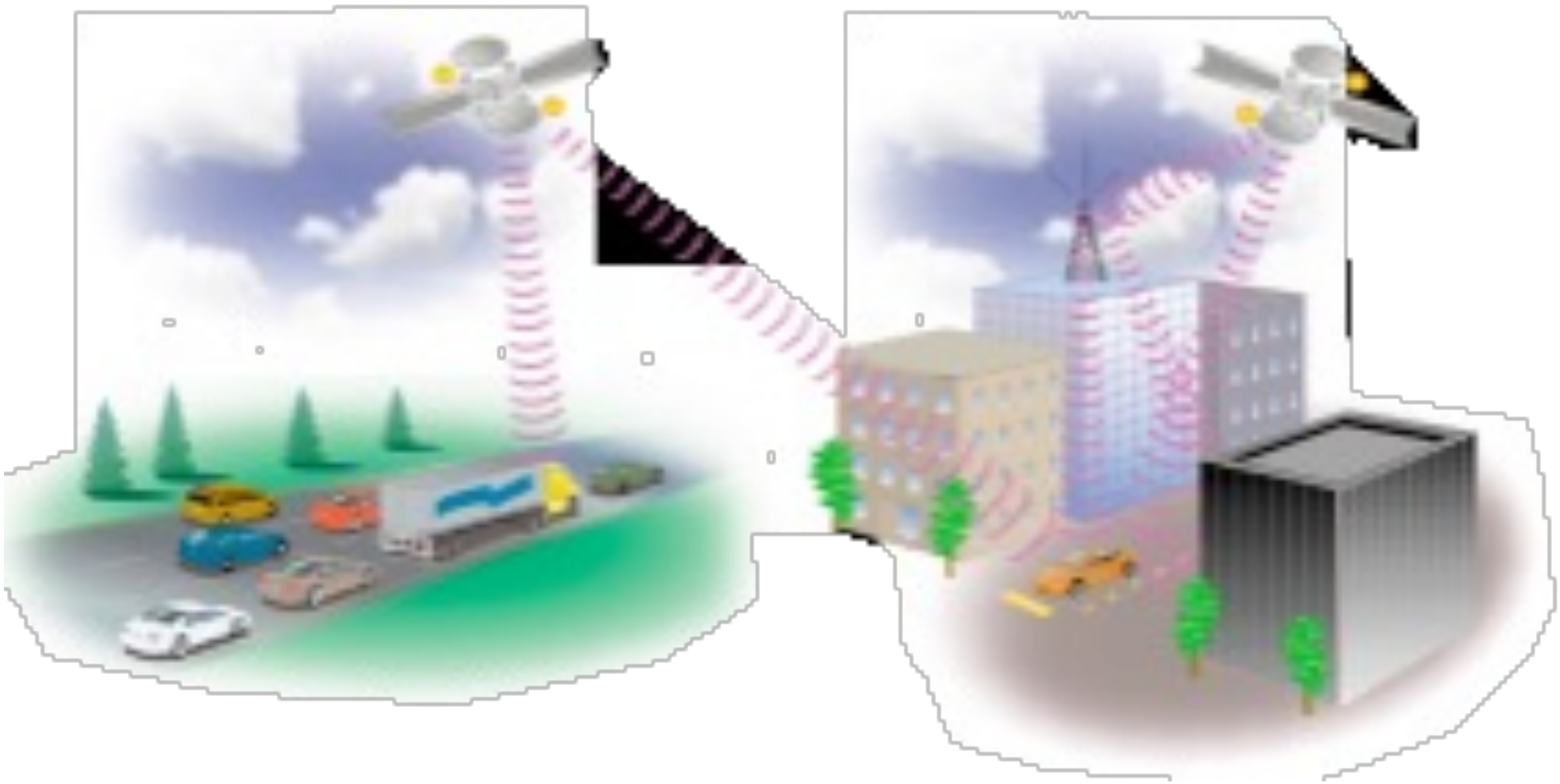

## Drawbacks

- <u>**Double payload on the HAPS**</u>
- Splitting connections
- Routing
- Complexity

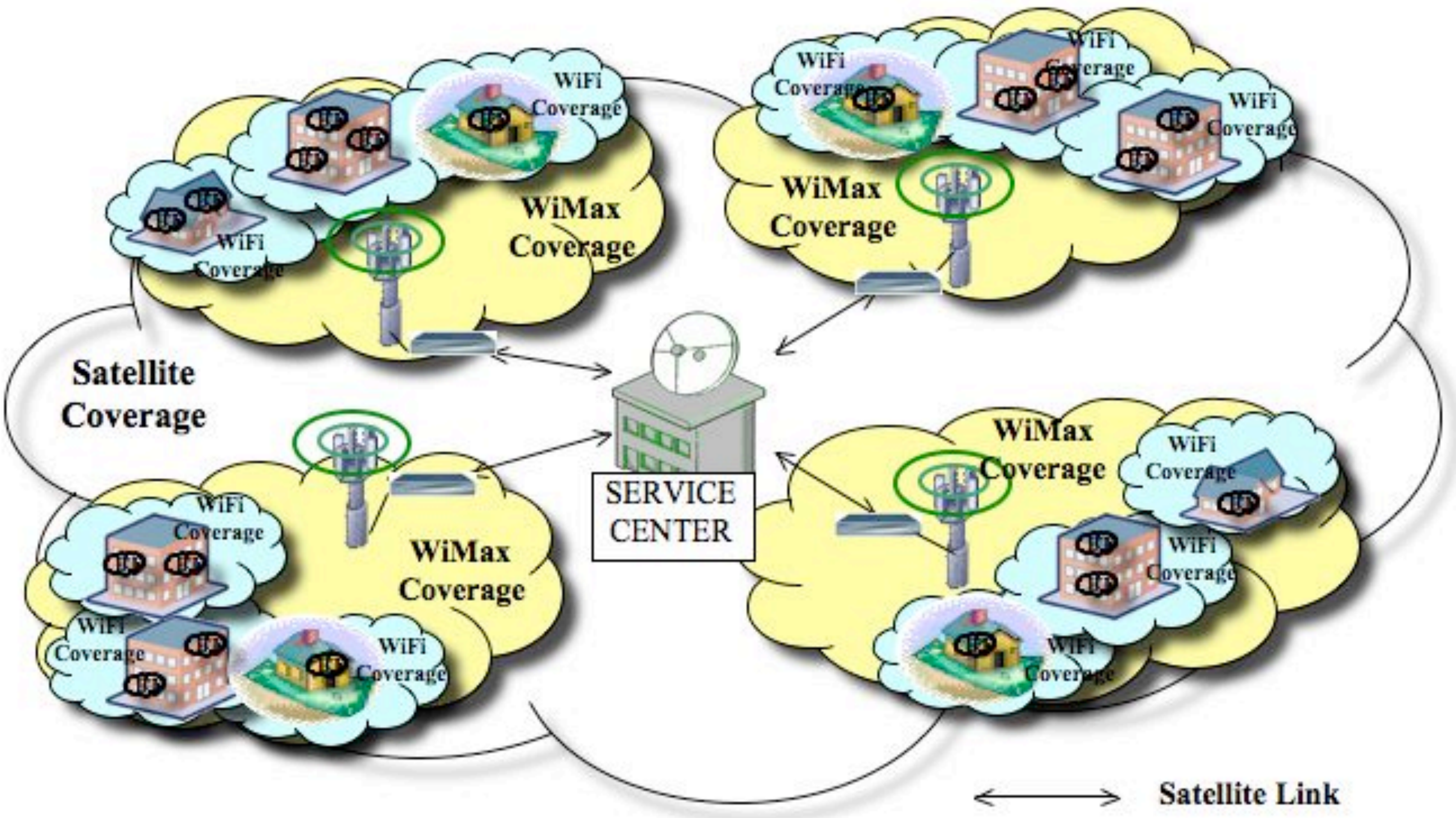
# Interworking in heterogeneous networks

- Wireless terrestrial systems can complement satellite networks
  - as gap filler of the satellite coverage due to shadowing
  - as terrestrial tail (to improve flexibility and capillarity)
- Satellite systems can complement wireless terrestrial systems
  - As gap filler due to not contiguous coverage
  - As backbone among BTS
  - To extend coverage (standard compatibility must be verified)
  - To provide efficient solutions to ensure ICN, CDN, SDN real global implementation

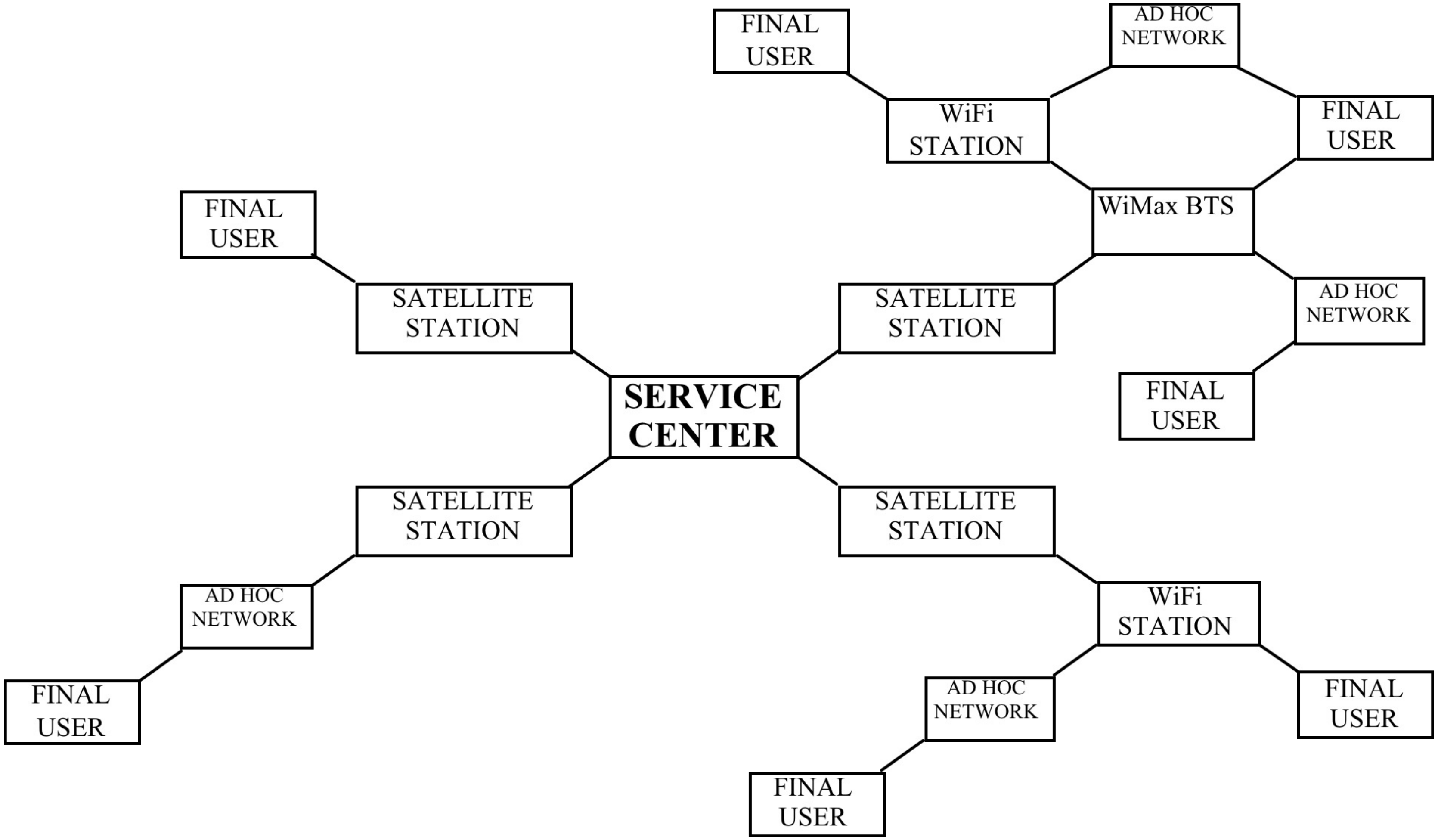
# Terrestrial systems fill the satellite gap



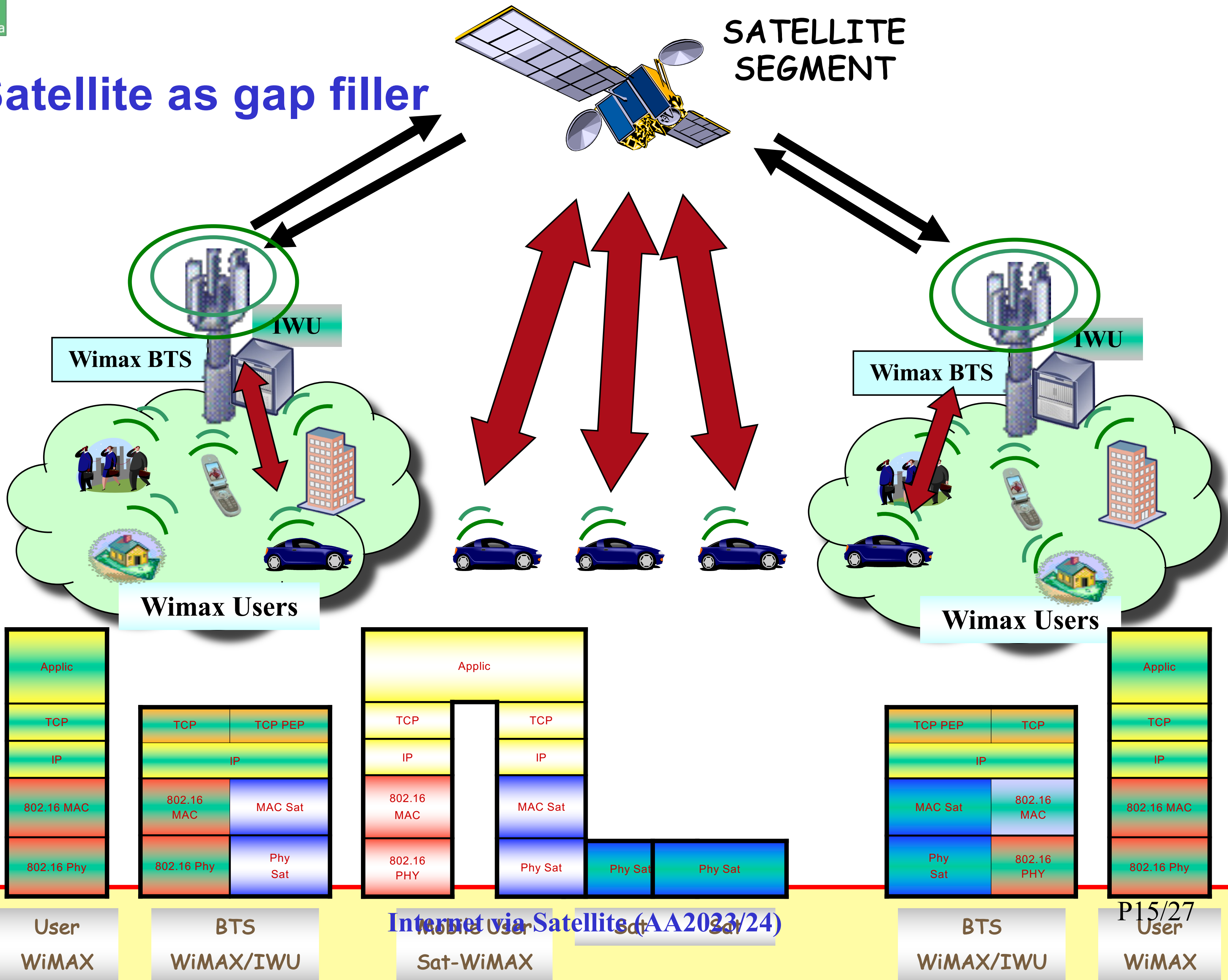
# Heterogeneous Network infrastructure



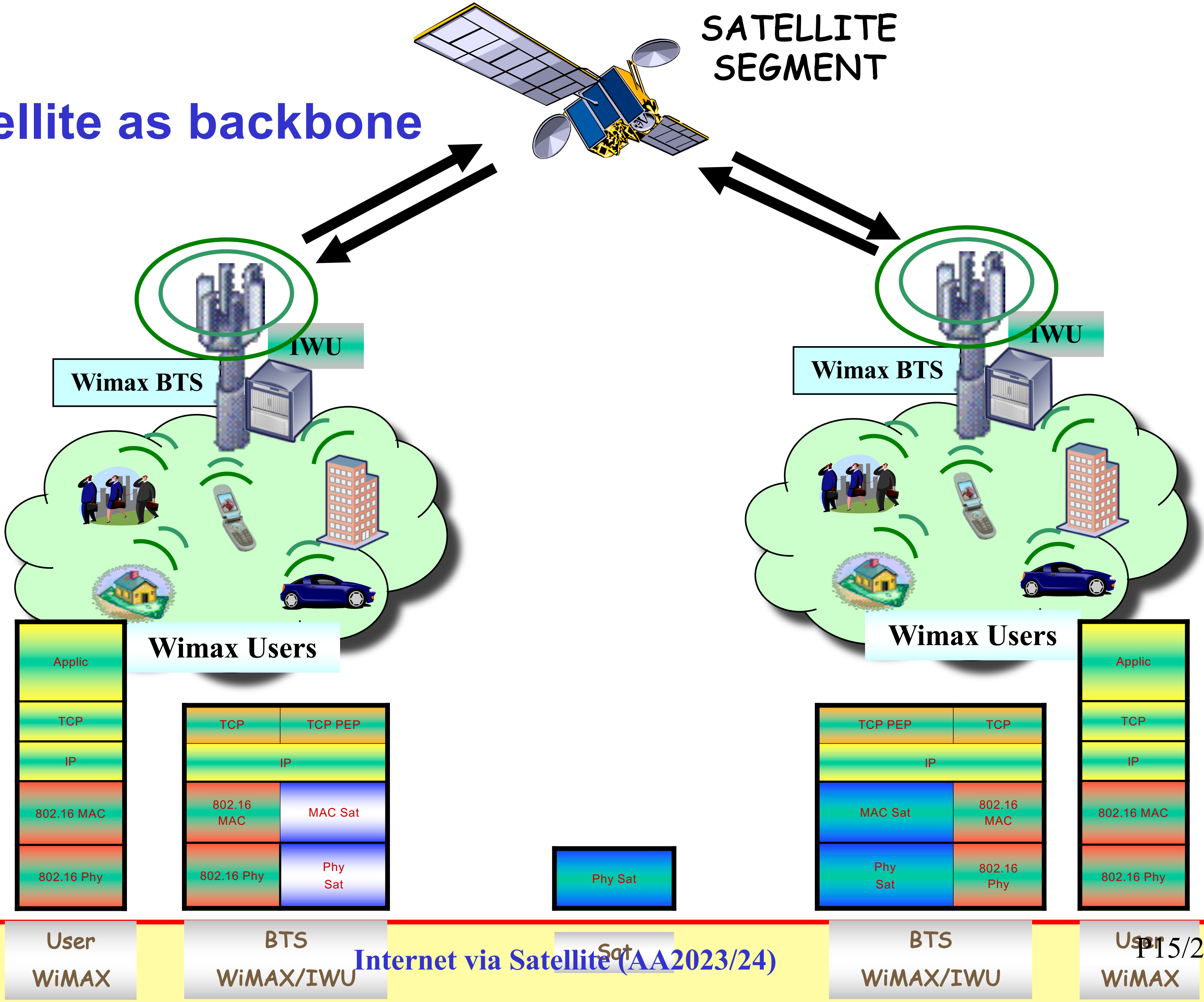
# Hybrid Network Topology



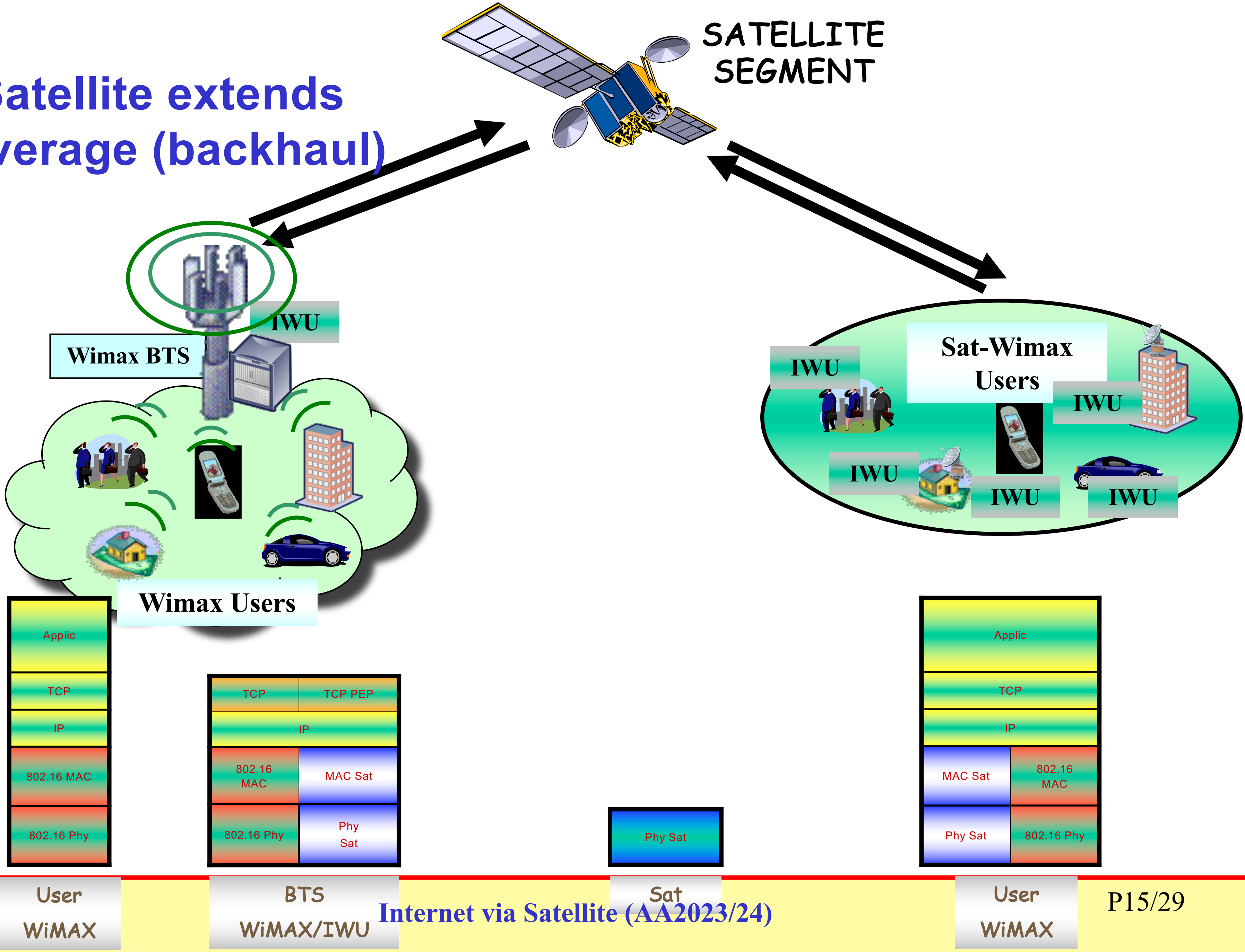
# Satellite as gap filler



# Satellite as backbone



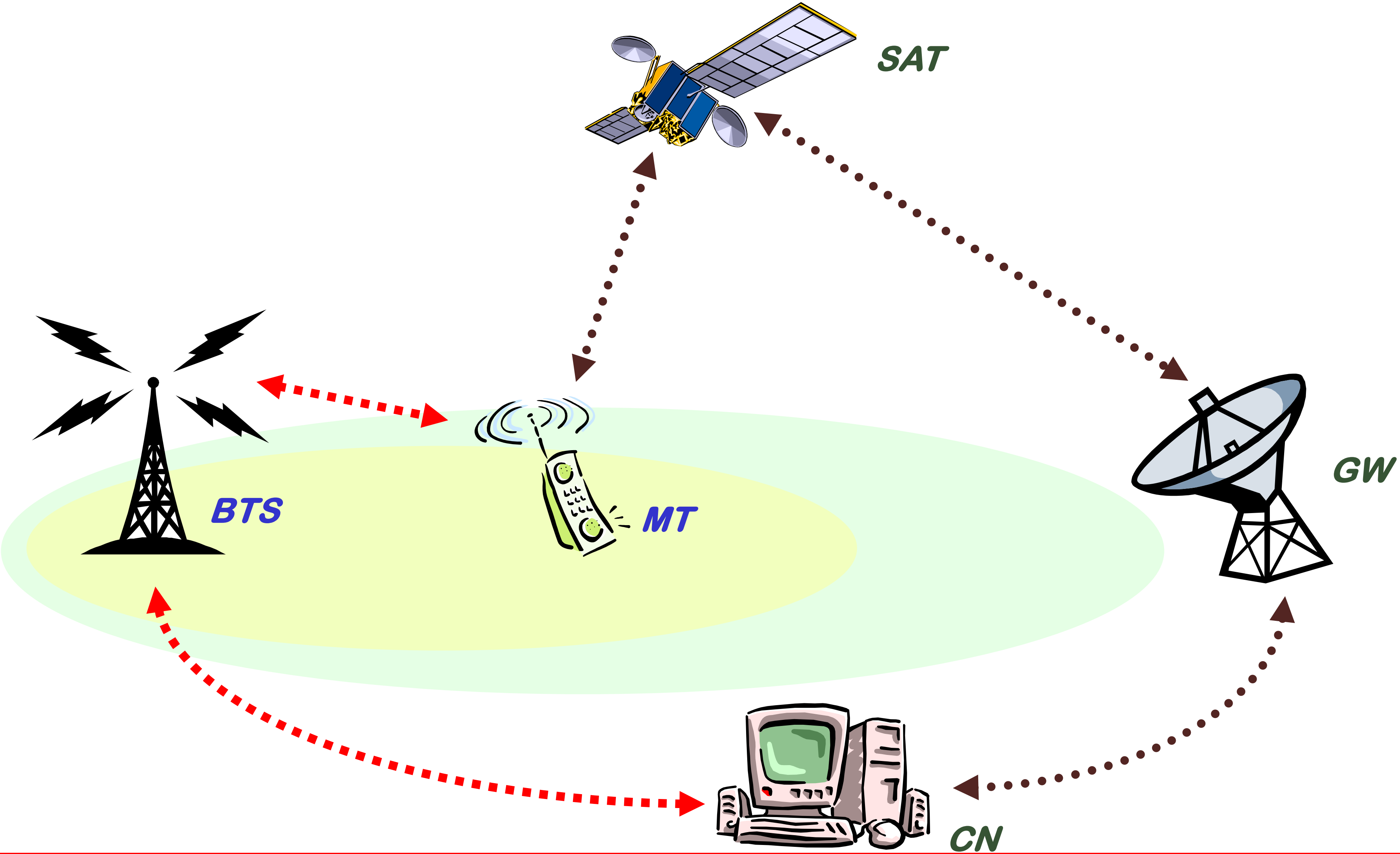
# Satellite extends coverage (backhaul)



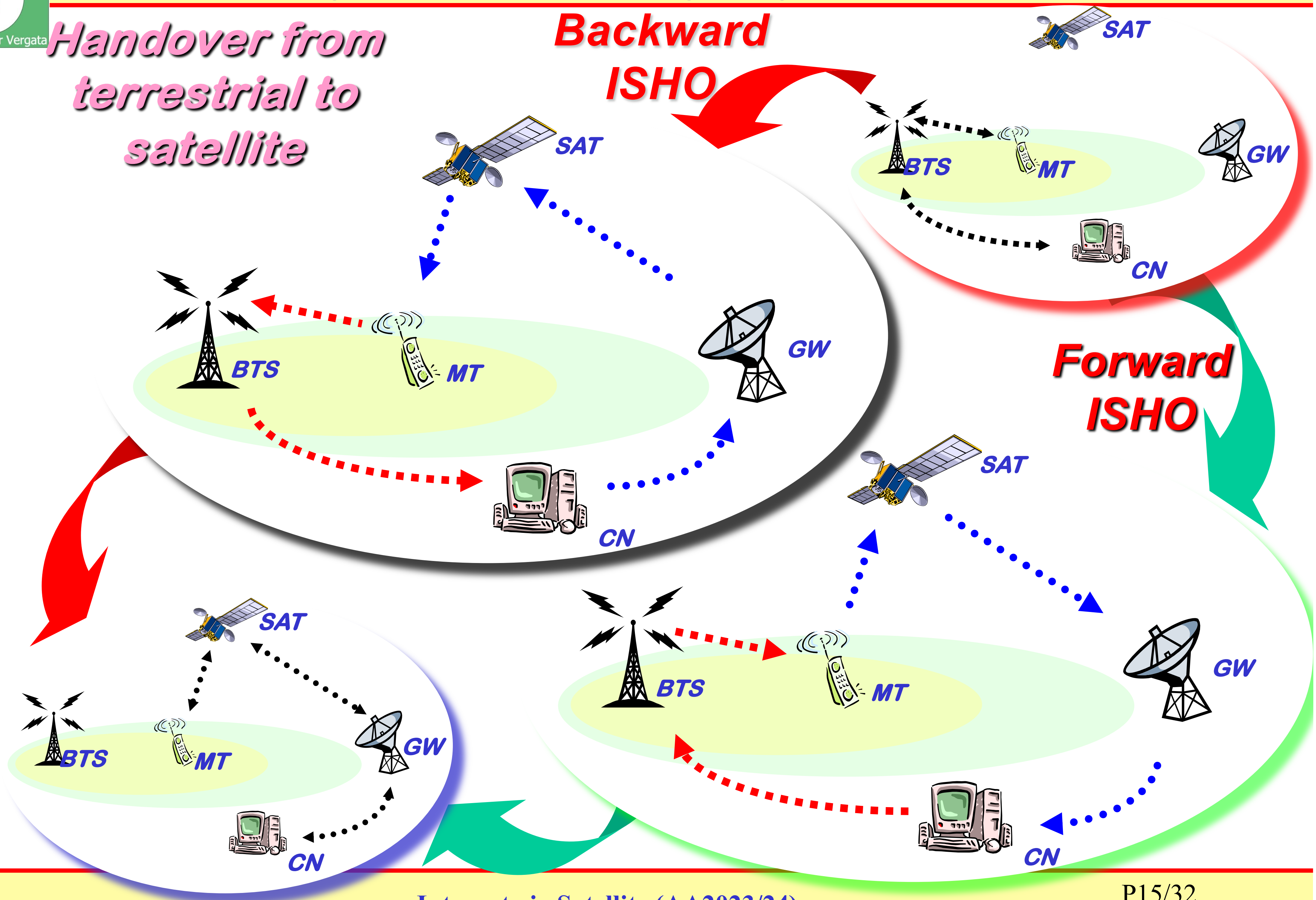
# Use of the satellite in the global infrastructures

Intersegment handover issues

# Intersegment Handover introduction



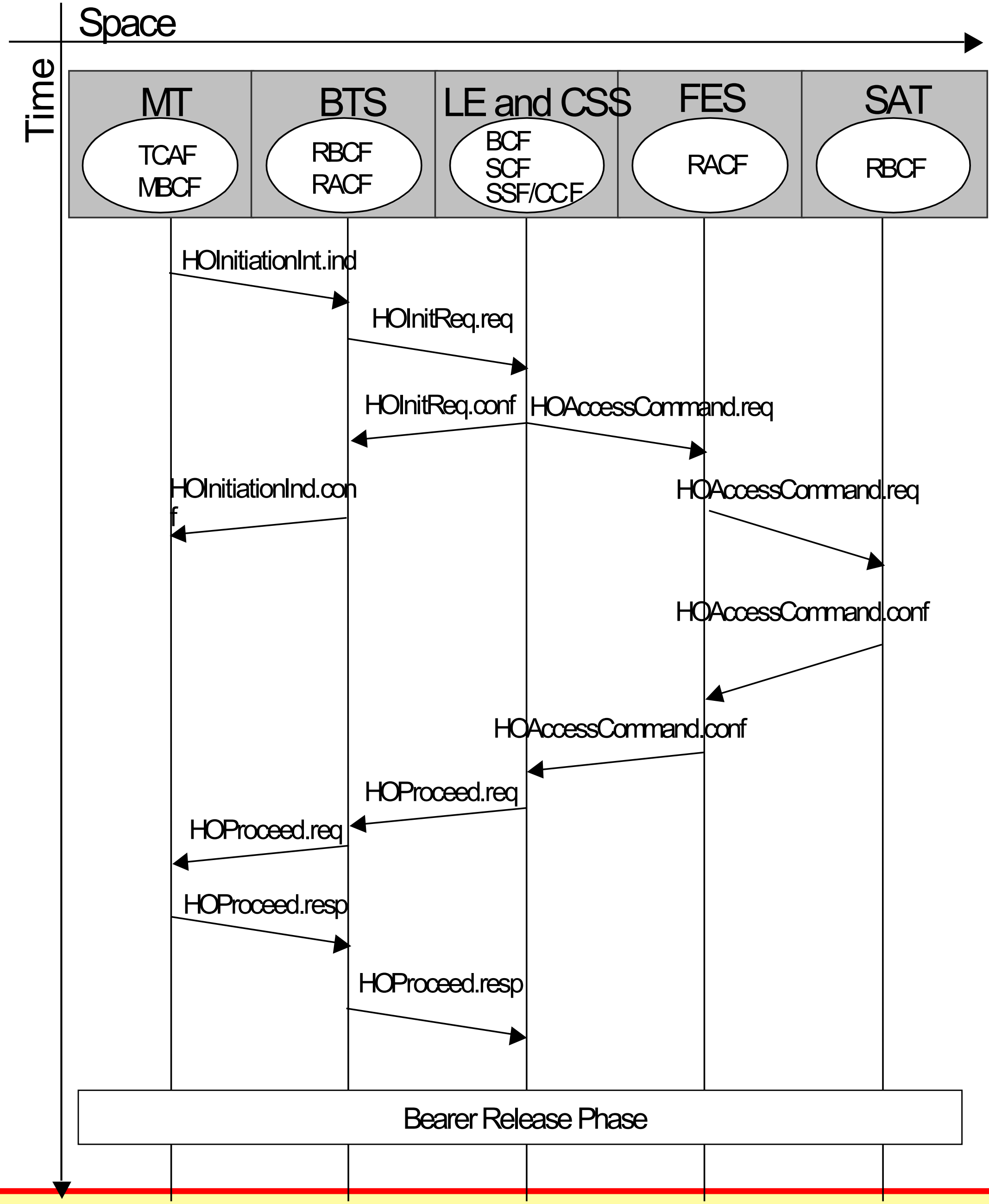
# Handover from terrestrial to satellite



# Handover from terrestrial to satellite

**Backward ISHO**

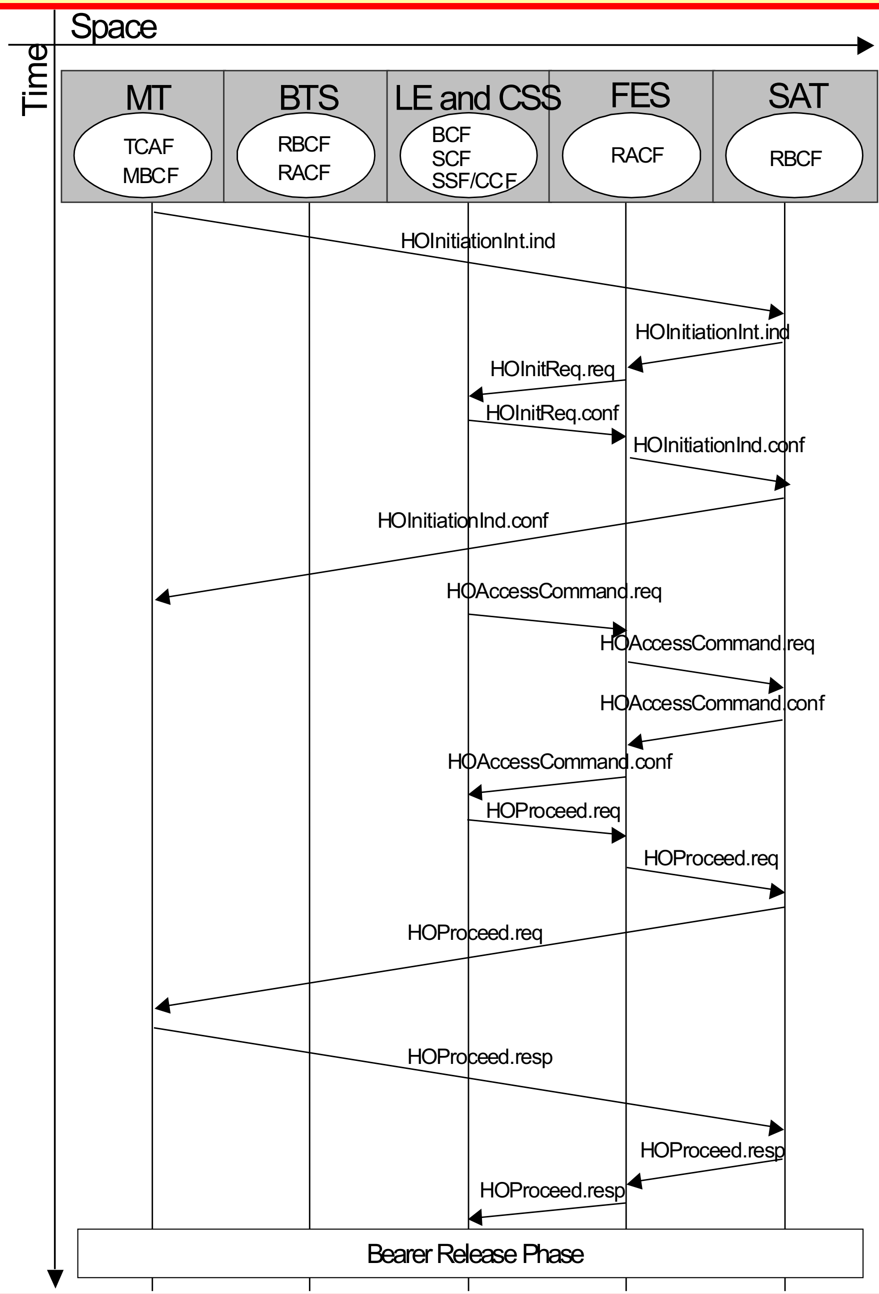
***UMTS proposed procedure***



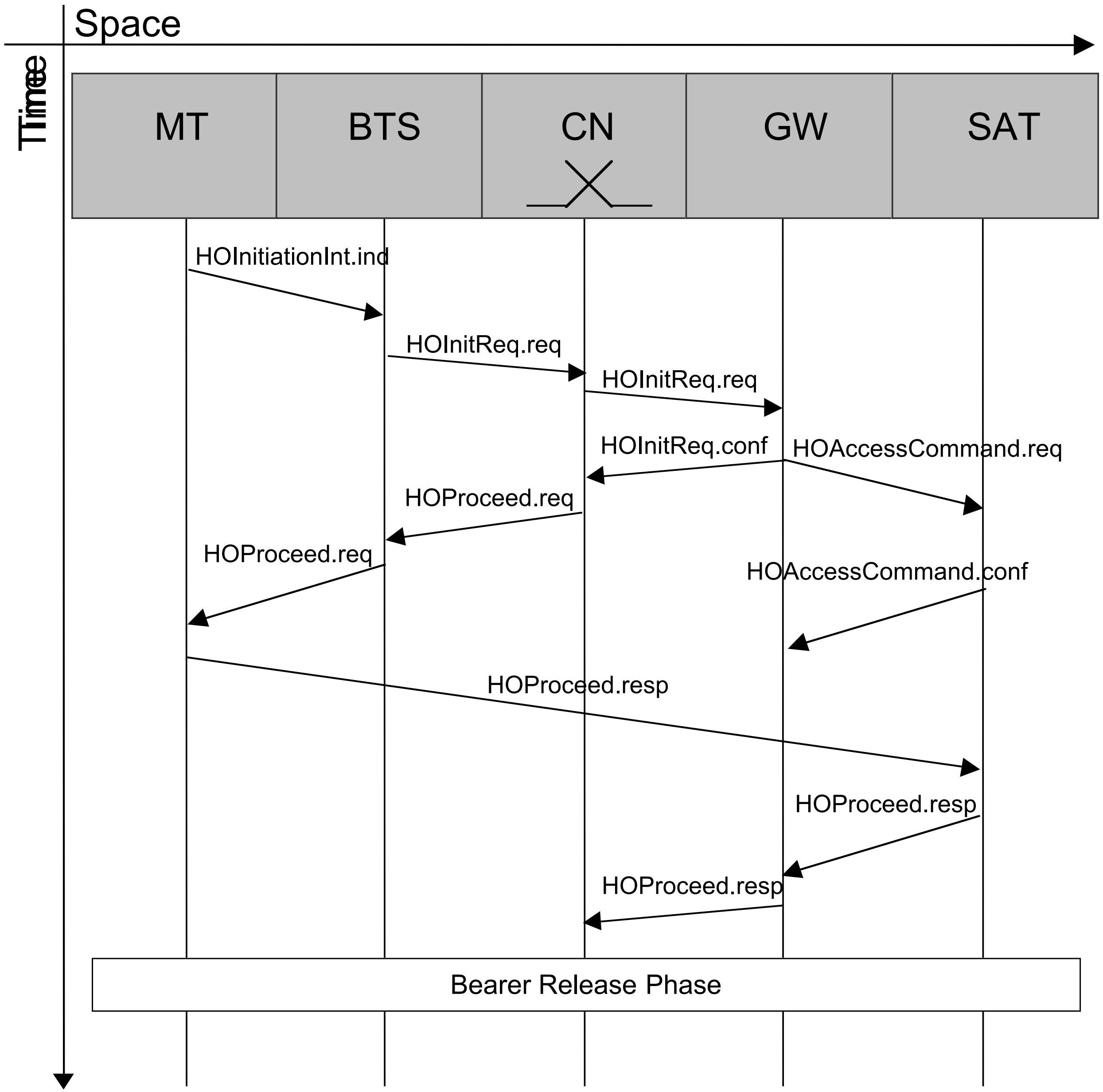
# Handover from terrestrial to satellite

**Forward ISHO**

**UMTS proposed procedure**

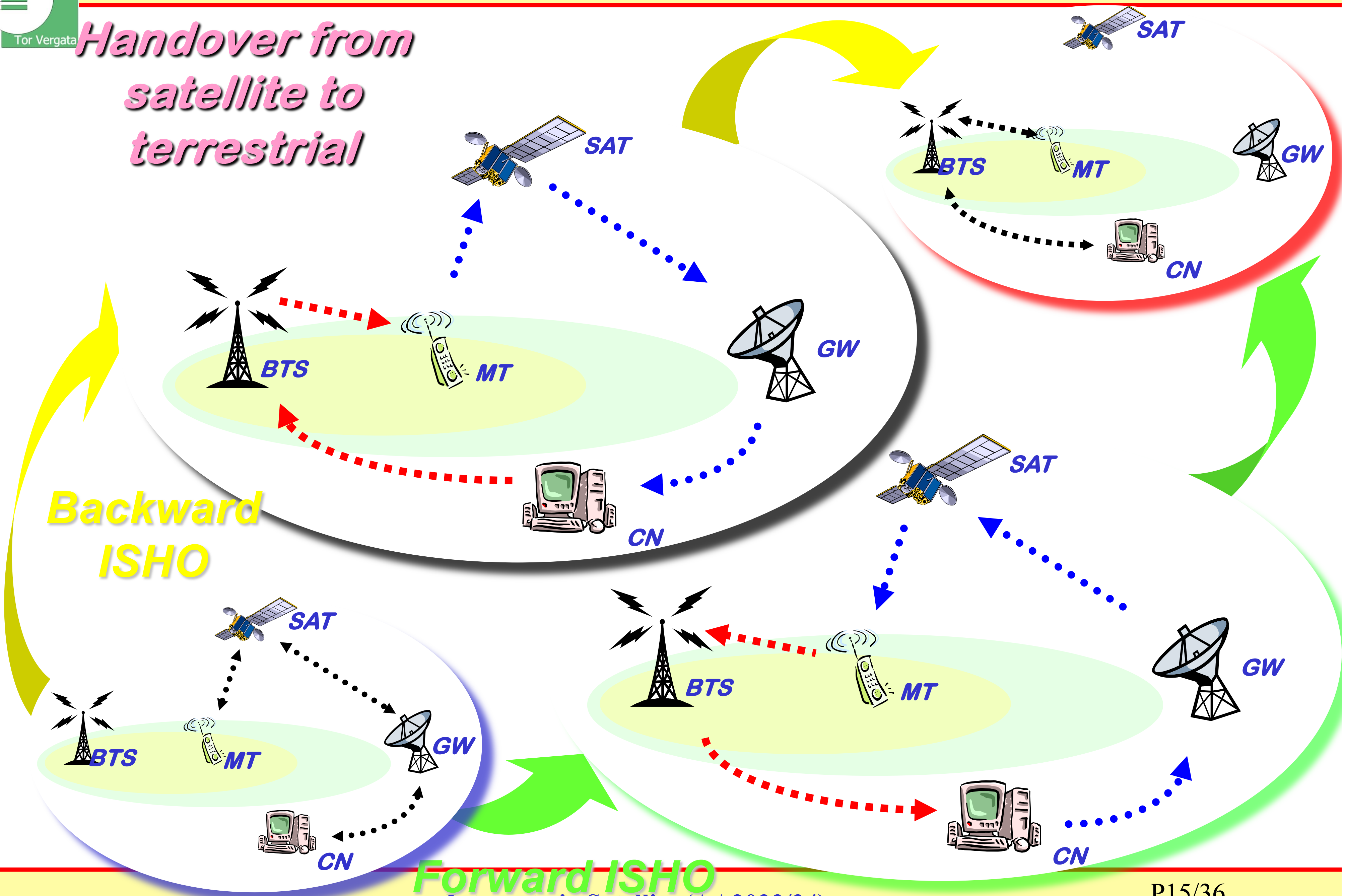


# Handover from terrestrial to satellite

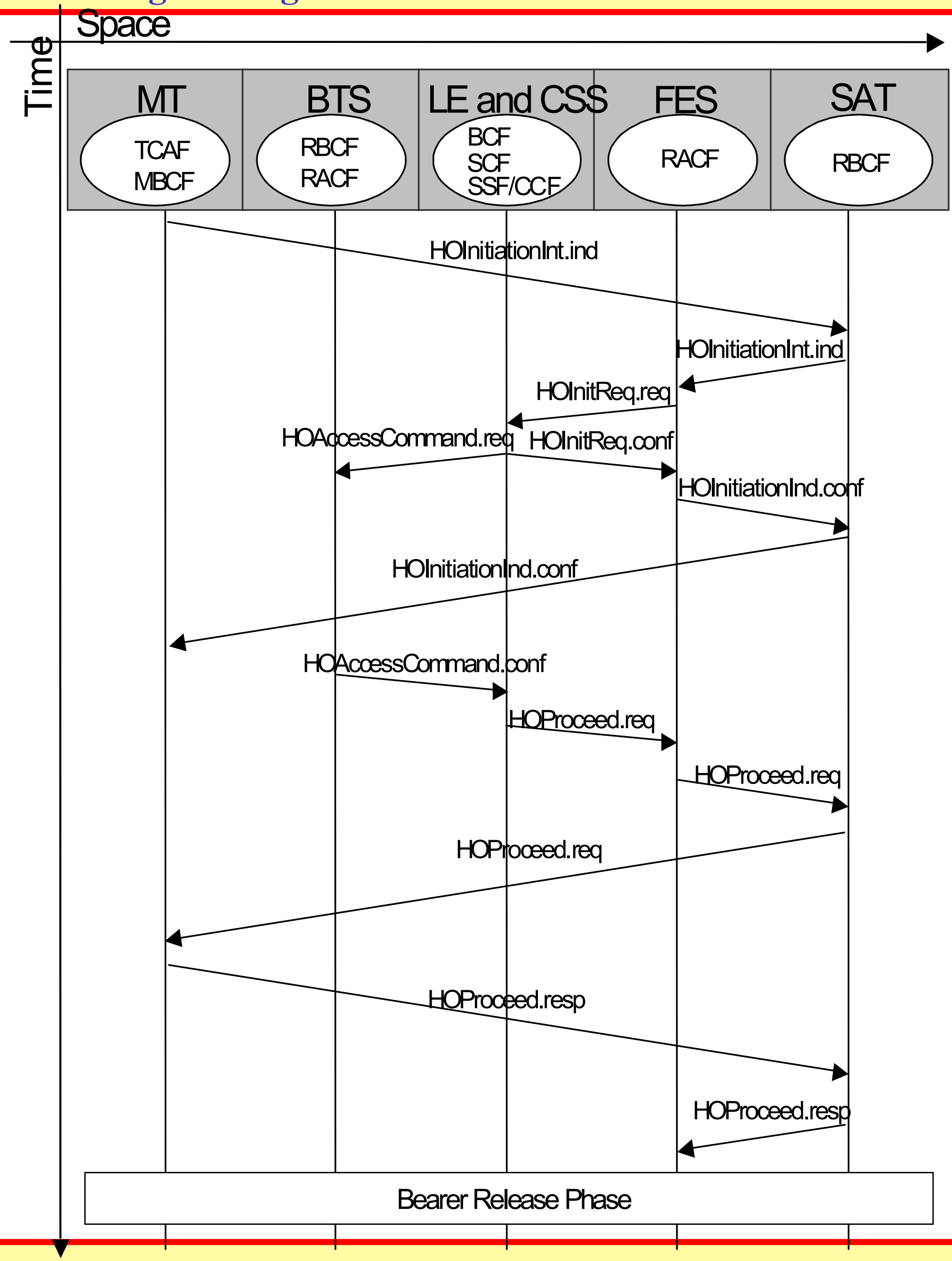



***Optimised procedure***

# Handover from satellite to terrestrial



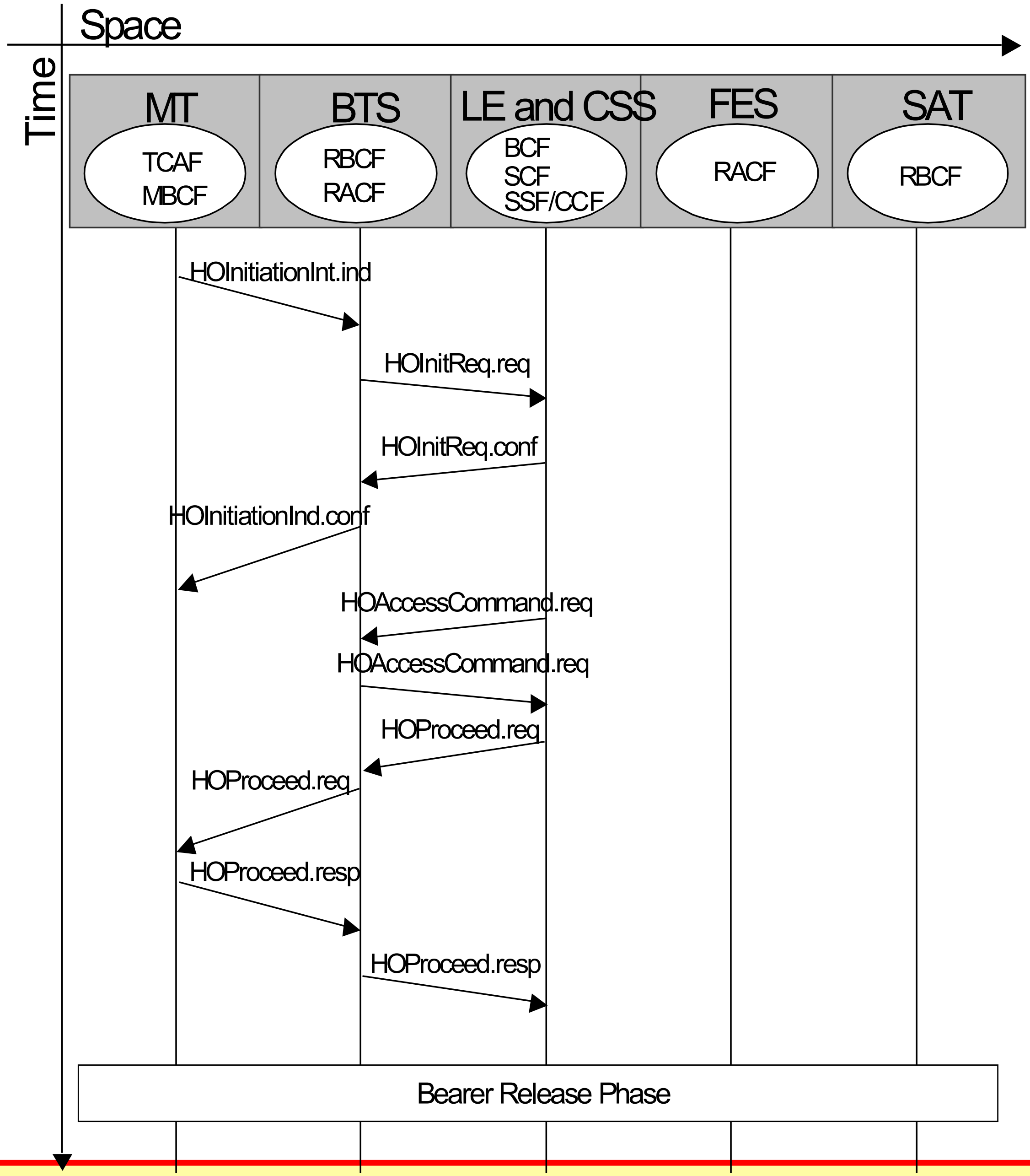
# Handover from satellite to terrestrial



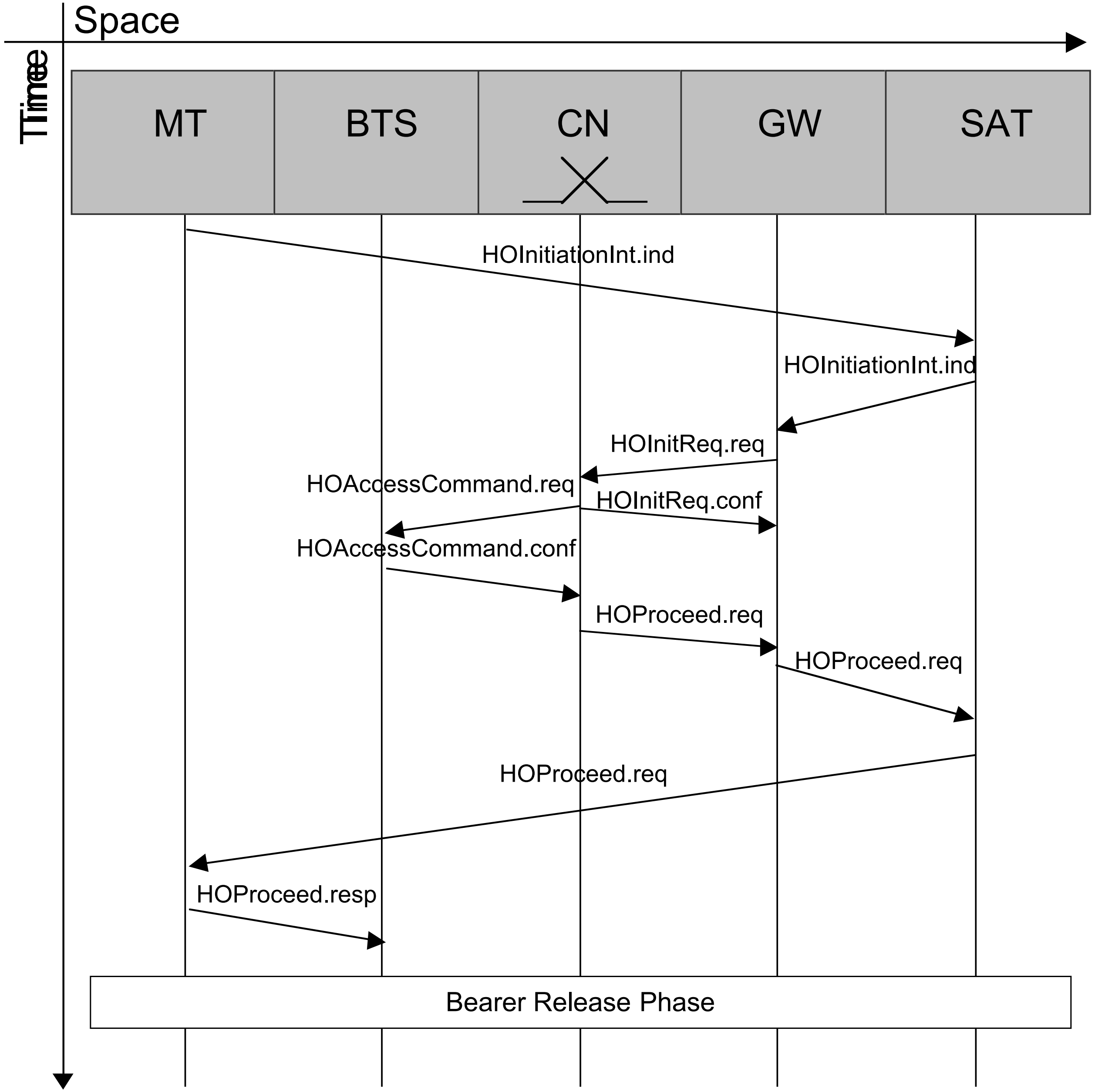

**Backward ISHO**

***UMTS proposed procedure***

# Handover from satellite to terrestrial

# Handover from satellite to terrestrial




**Optimised procedure**

# Simulation scenario

**Constellations** → Iridium, Globalstar, ICO

**Gateway** → Lat: 41.9°, Long: 12.5° E

**Sectors** → 4 sectors – 800 km radius

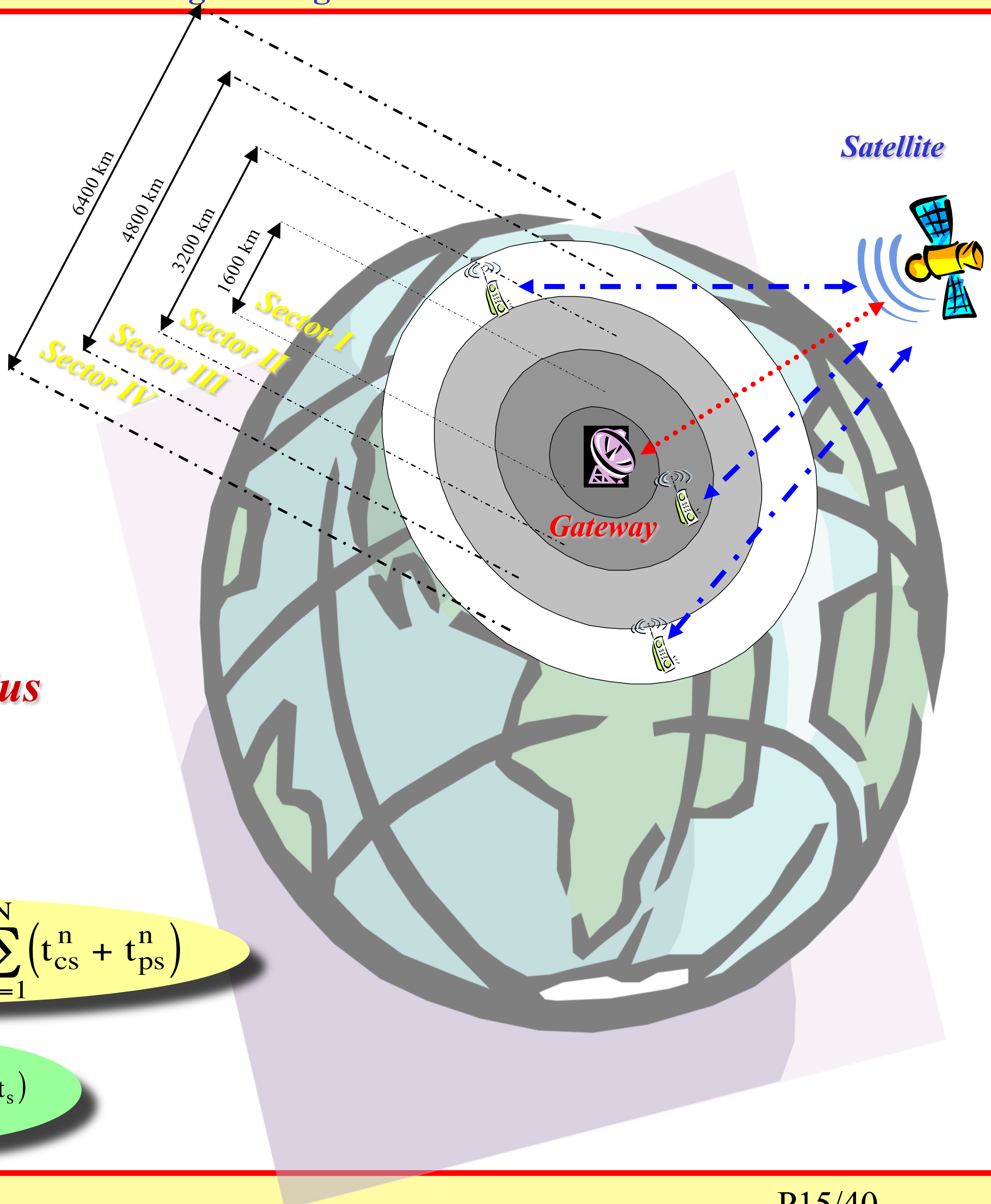
**Users** → 100 users in each sector

**User delay** →

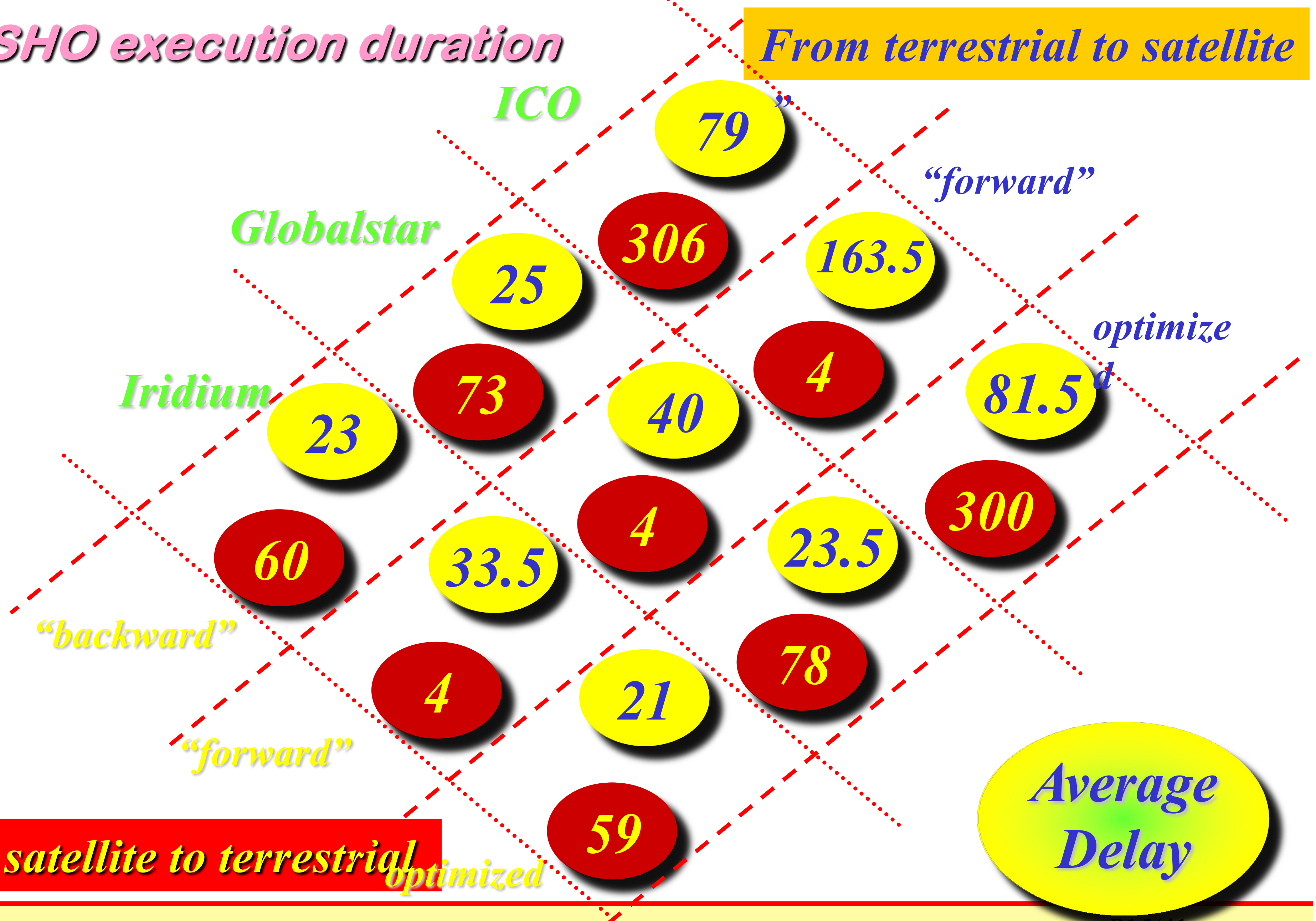
$$d_i(t_s) = \sum_{k=1}^{5} R_k d_i^k(t_s) + \sum_{n=1}^{N}\left(t_{cs}^n + t_{ps}^n\right)$$

**Average delay** →

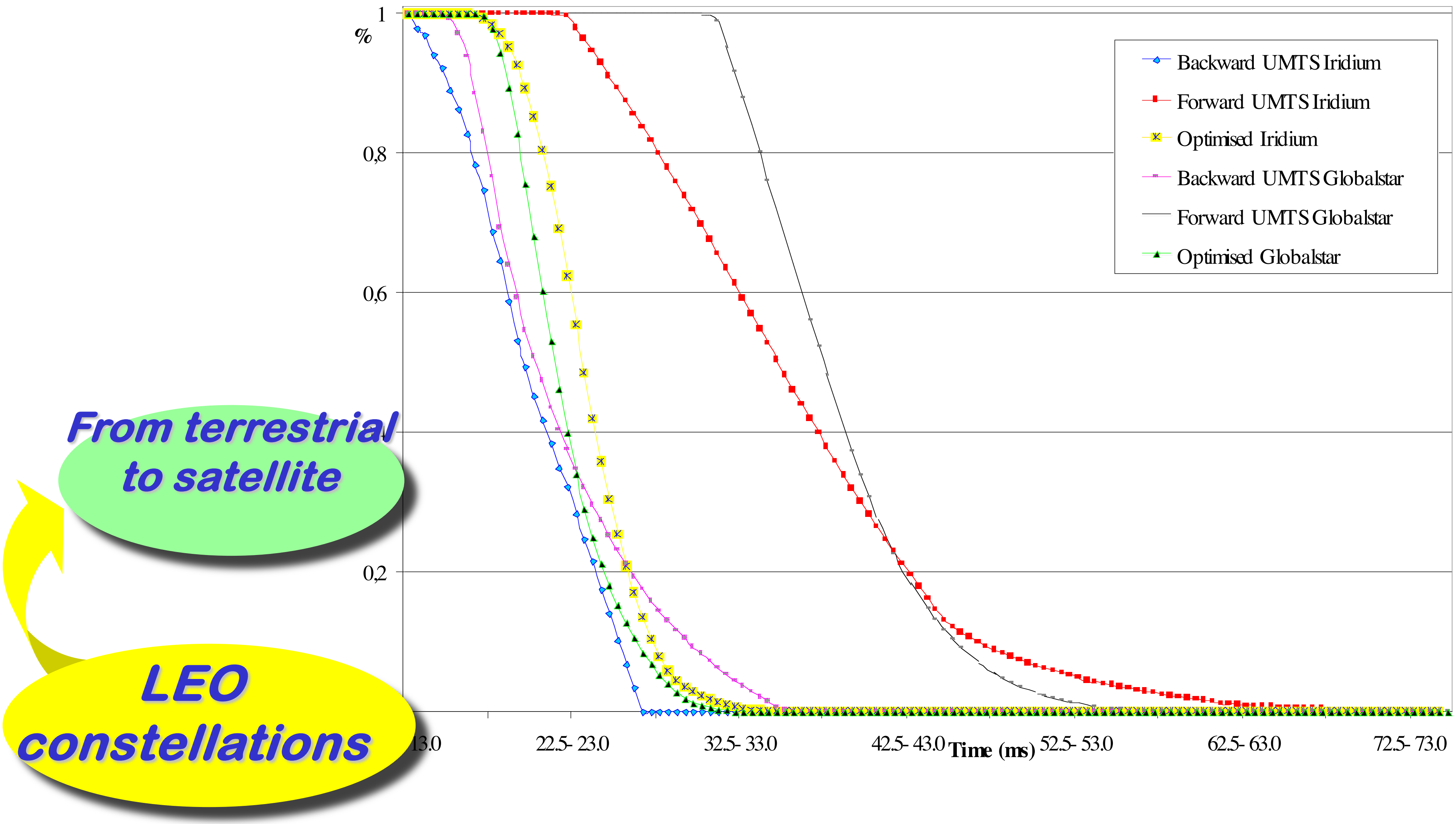
$$d_A = \frac{1}{MT}\sum_{s=1}^{S}\sum_{m=1}^{M} d_i(t_s)$$



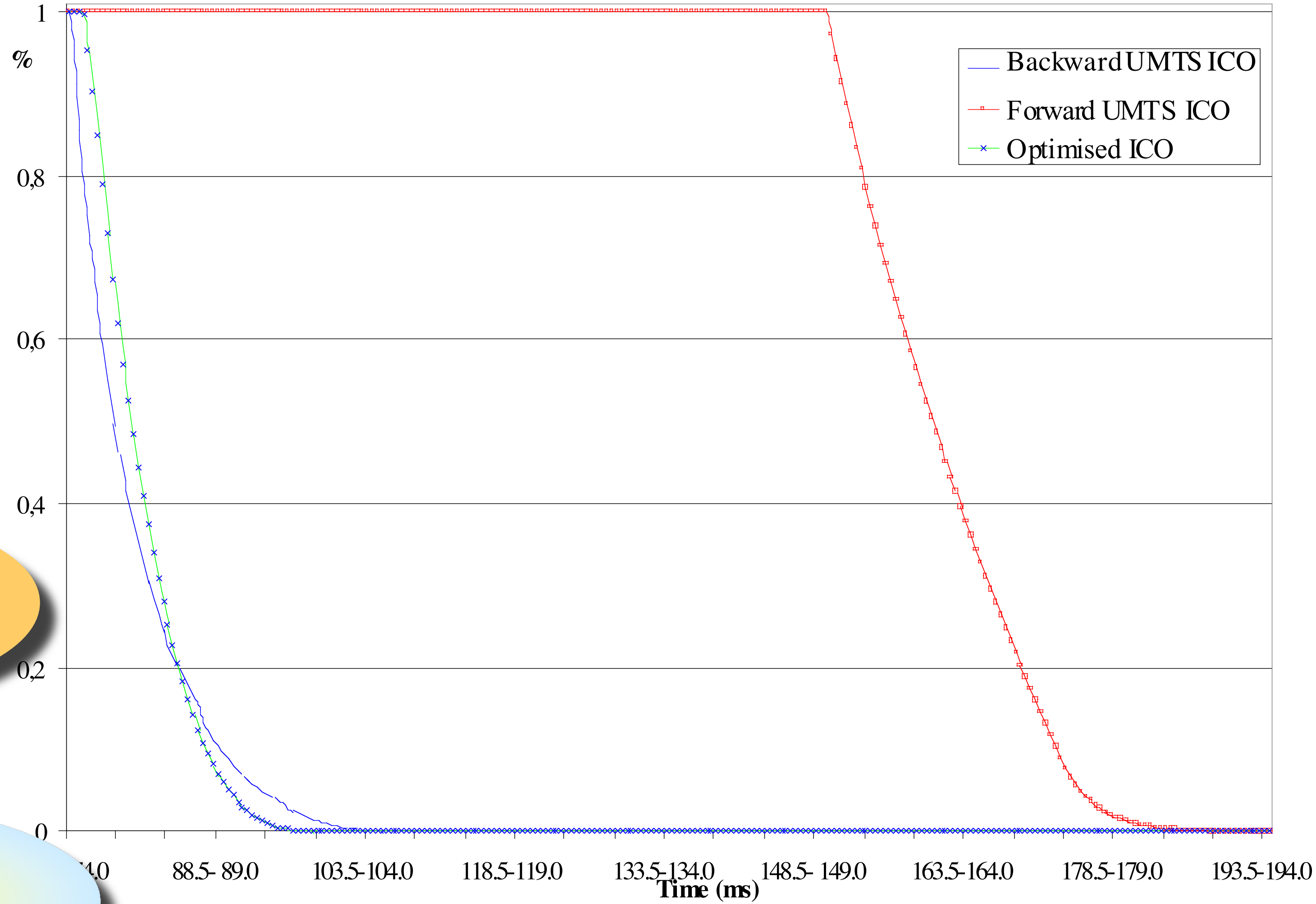
# ISHO execution duration



# HO failure probability



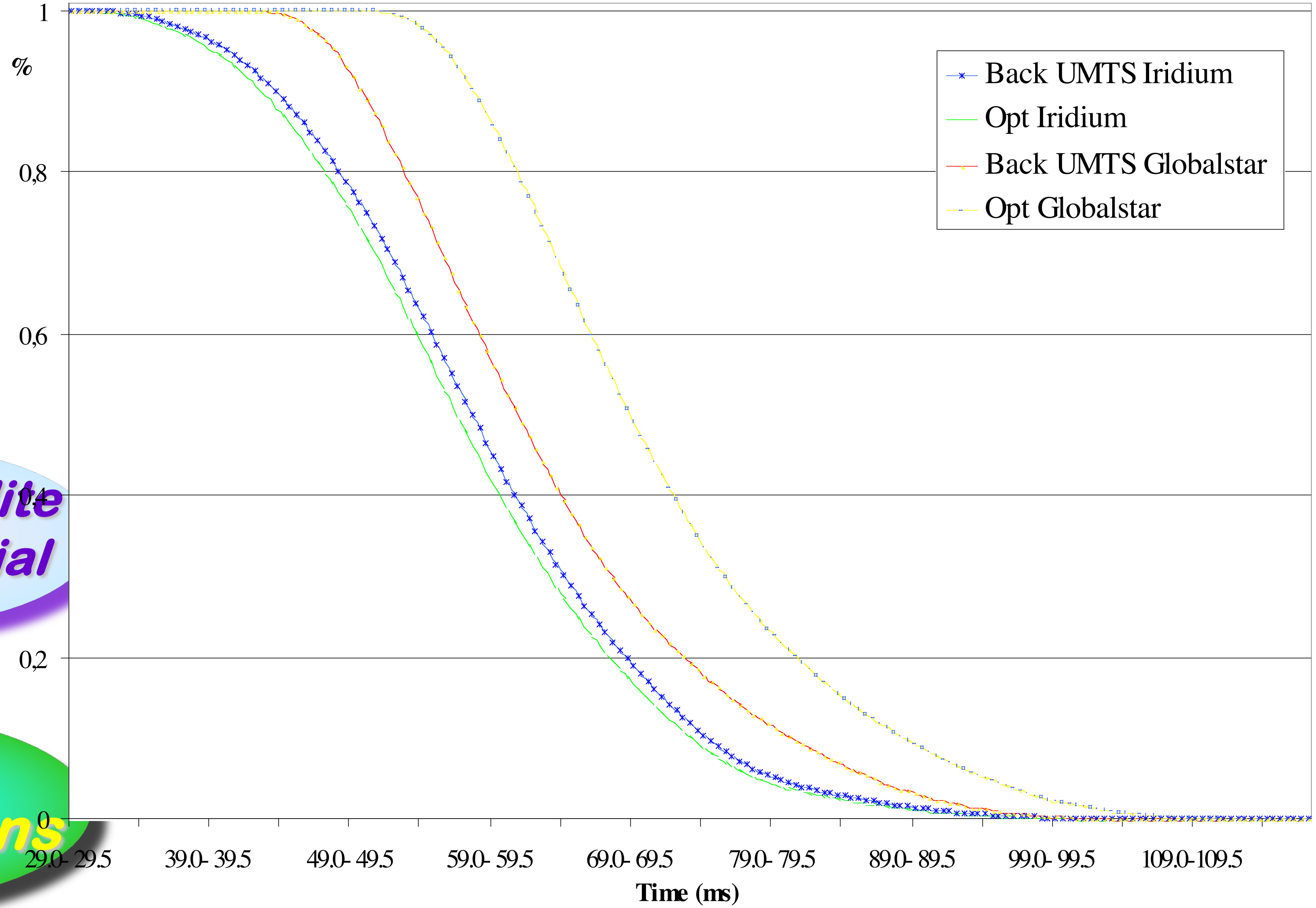
# HO failure probability

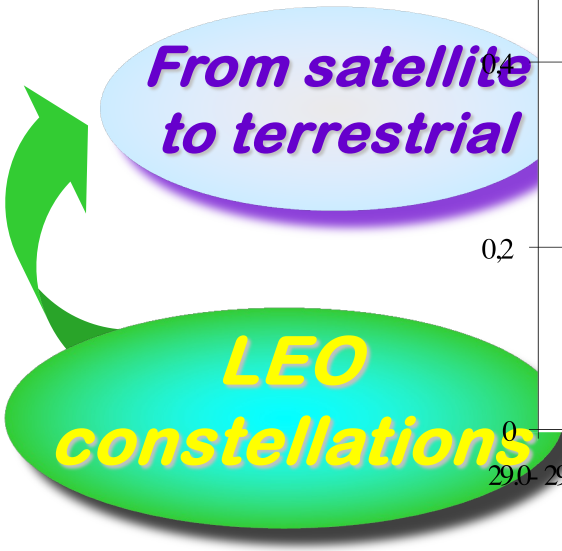



From terrestrial to satellite

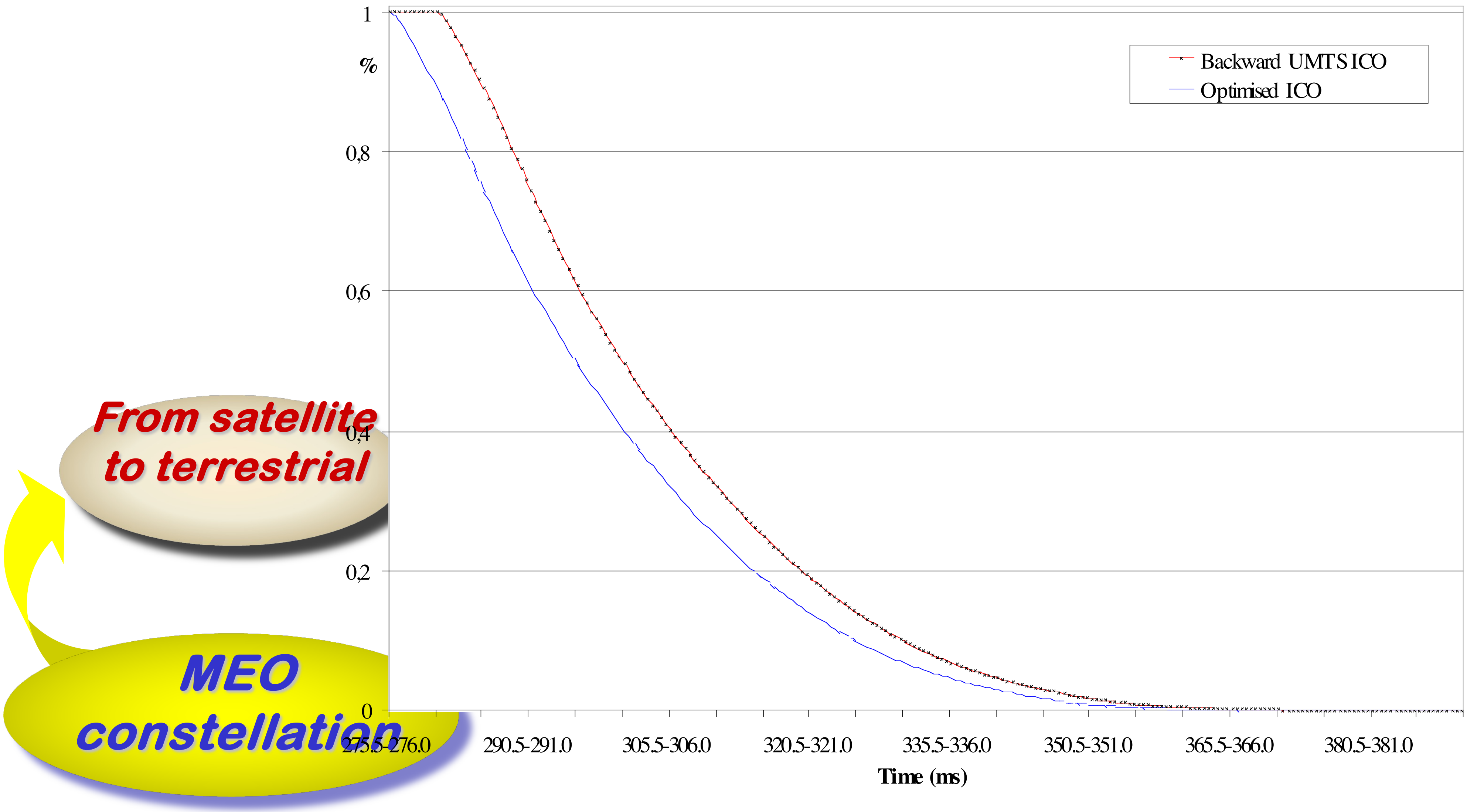
MEO constellation

# HO failure probability

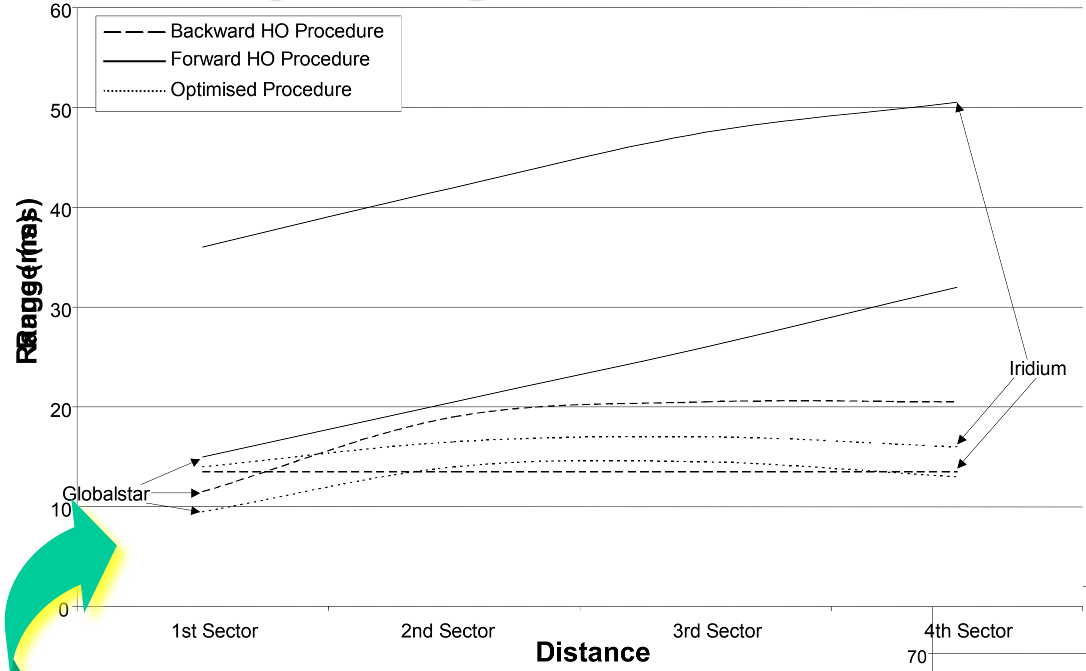


# HO failure probability



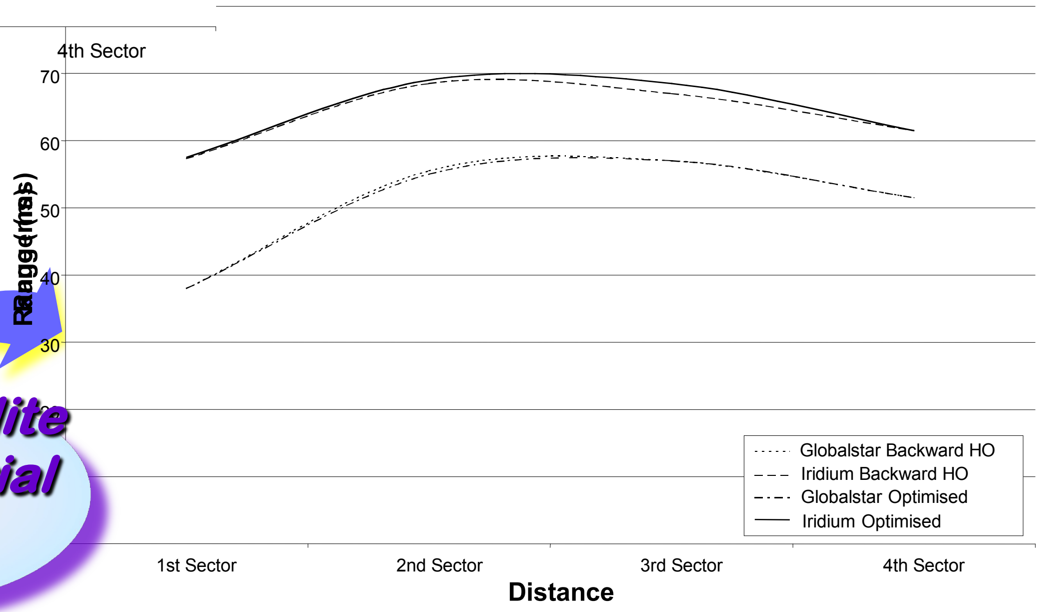
# Delay Range



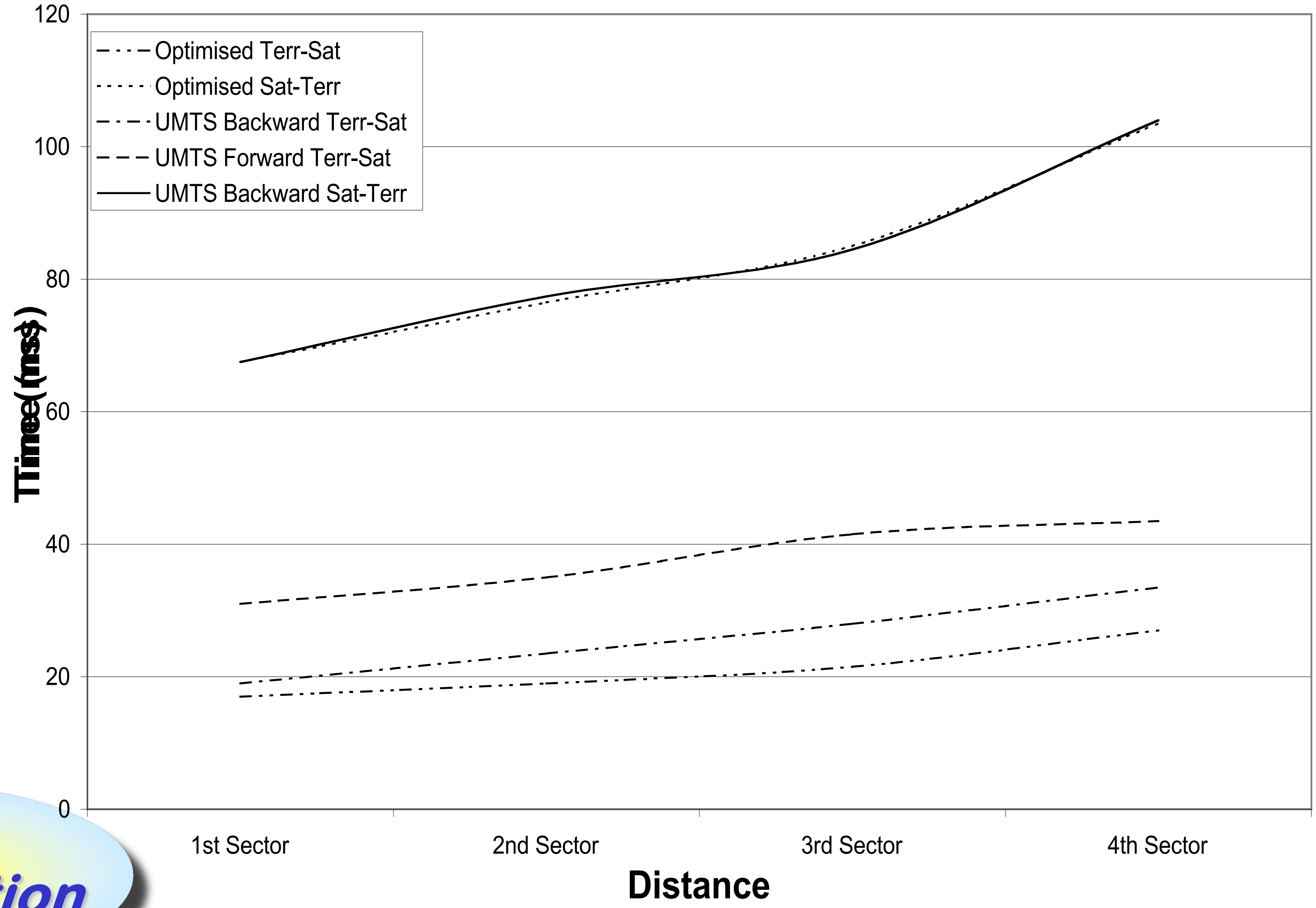

From terrestrial to satellite

LEO constellations

From satellite to terrestrial

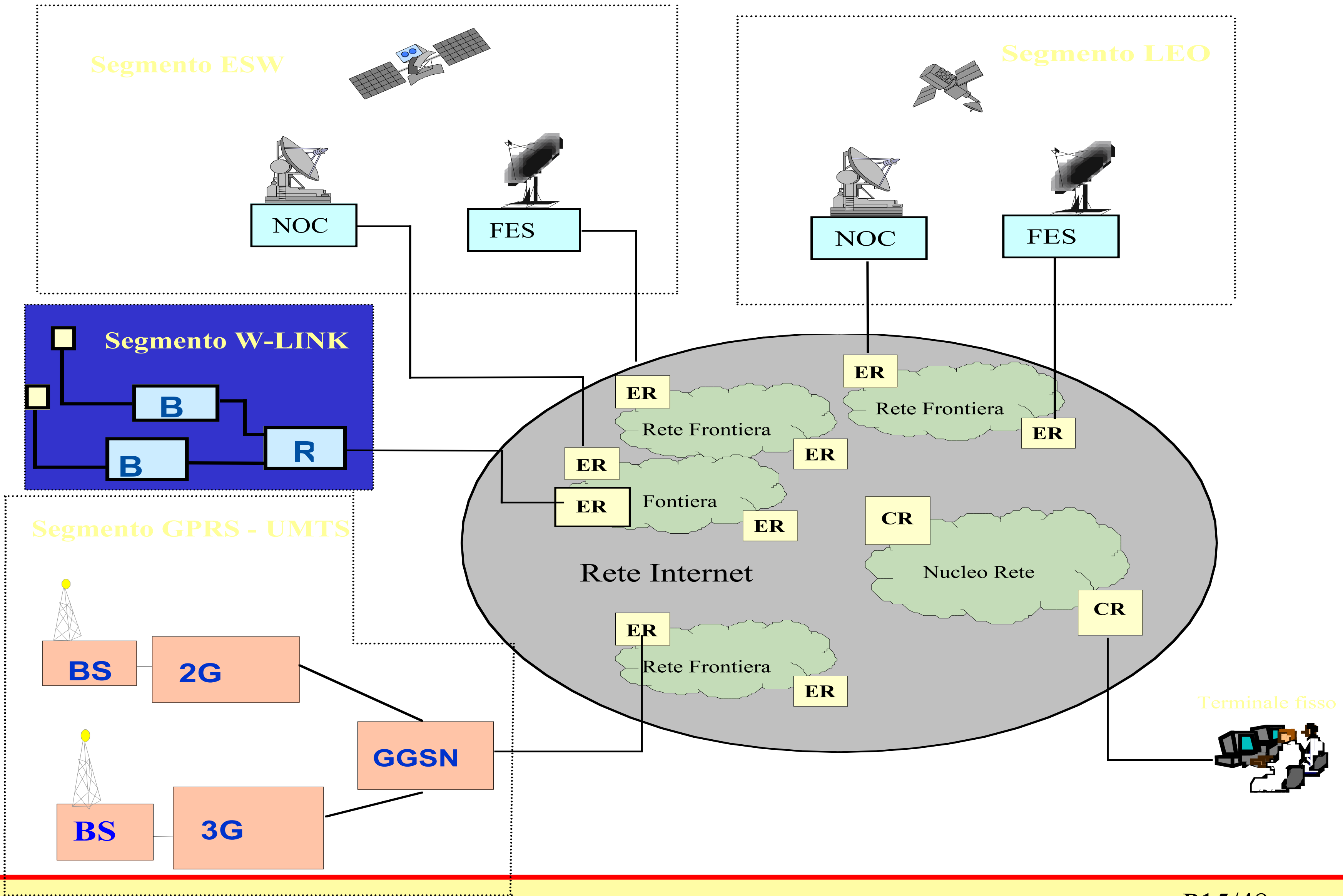


# Delay range

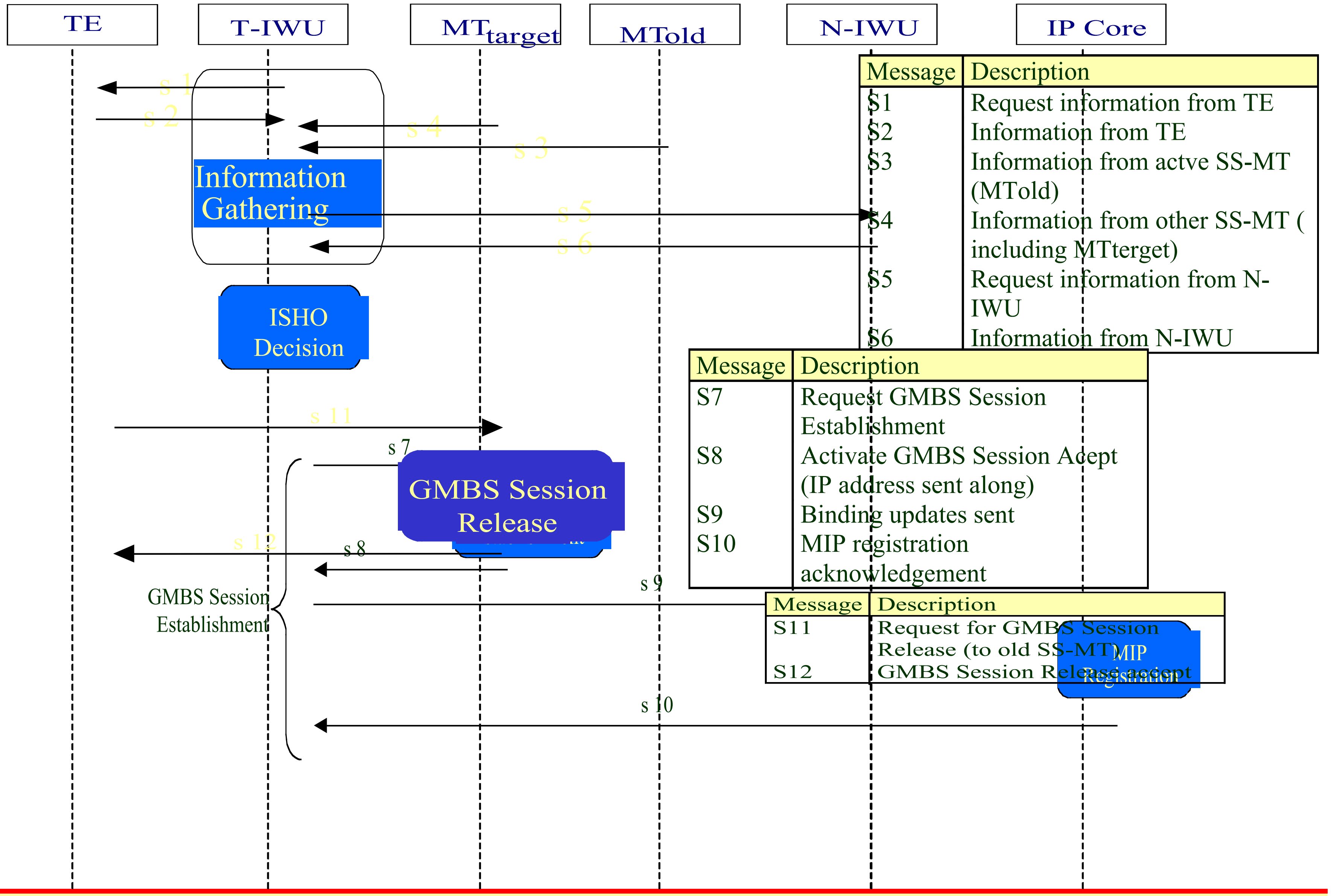



**MEO constellation**

# SUITED architecture



# Handover in multi segment system




| Message | Description |
|---|---|
| S1 | Request information from TE |
| S2 | Information from TE |
| S3 | Information from actve SS-MT (MTold) |
| S4 | Information from other SS-MT ( including MTterget) |
| S5 | Request information from N-IWU |
| S6 | Information from N-IWU |

| Message | Description |
|---|---|
| S7 | Request GMBS Session Establishment |
| S8 | Activate GMBS Session Acept (IP address sent along) |
| S9 | Binding updates sent |
| S10 | MIP registration acknowledgement |

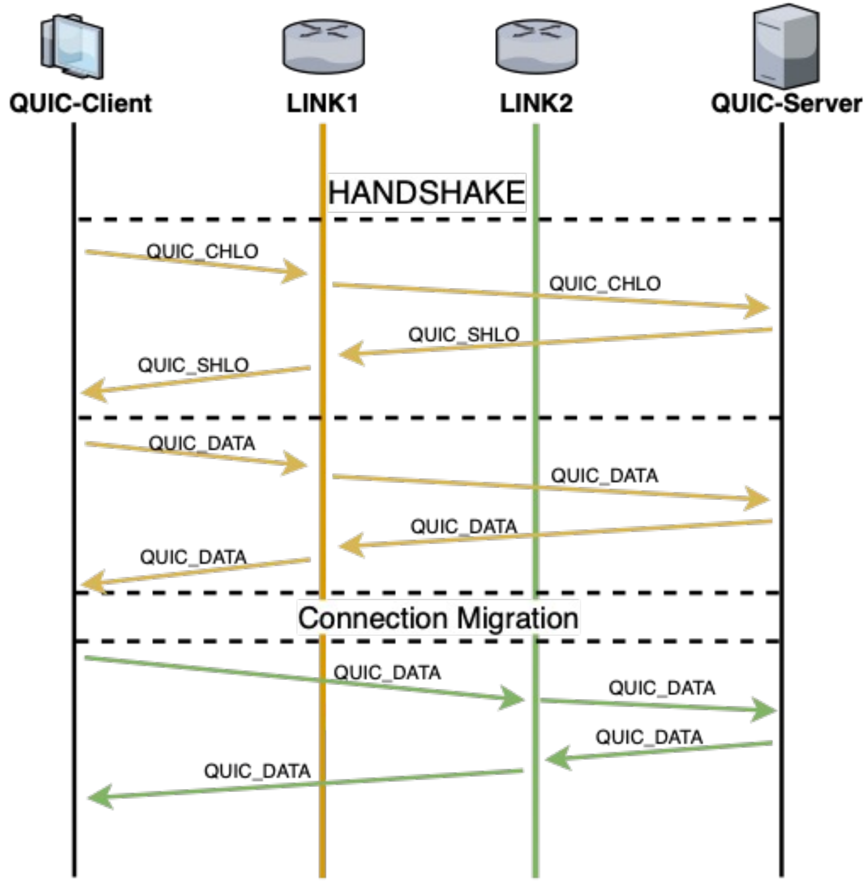
| Message | Description |
|---|---|
| S11 | Request for GMBS Session Release (to old SS-MT) |
| S12 | GMBS Session Release accept |

# Use of the satellite in the global infrastructures

## Upper layers issues

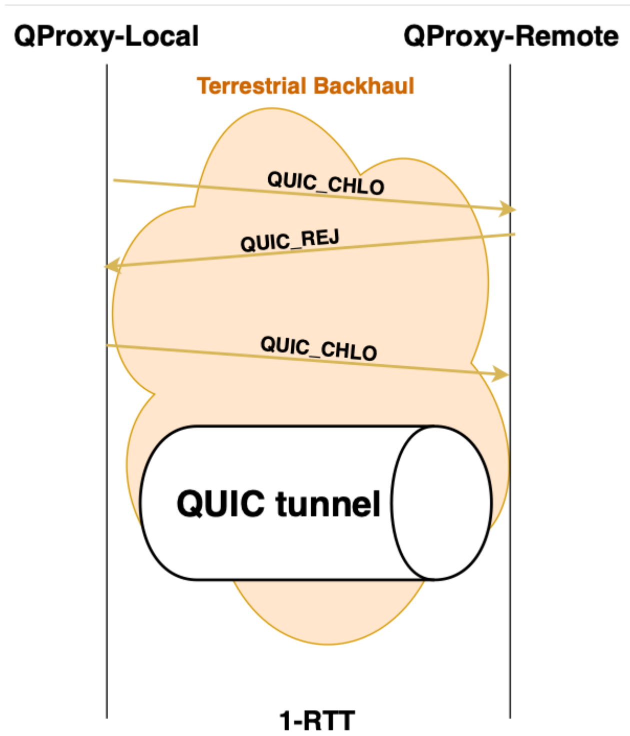
# Handover managed at transport and application layer

- **QUIC functions considered**
- Connection migration allows to **change dynamically** the communication path within different subnets



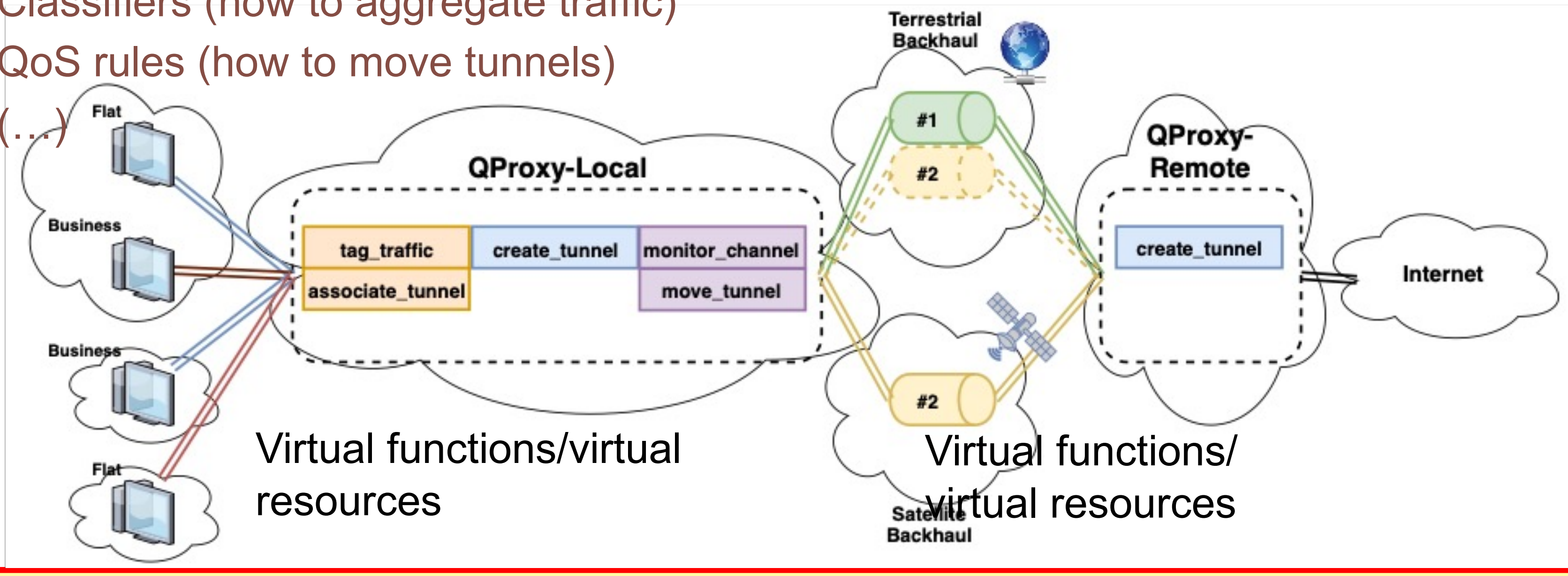
# QUIC-tunnel concept

- A tunnel is considered as a relation between two entities located at the edges of the network
  - QProxy-Local
  - QProxy-Remote
- QUIC functions are extracted and adapted to a multi-link scenario:
  - **Low latency tunnel establishment**
  - **Tunnel migration**
- Within a single QUIC-tunnel several TCP connections can be **aggregated,** according to specific rules (priority, application, etc.)



# QUIC-tunnel enabled as Virtual Function

- QUIC-tunnel as VNFs: the QUIC tunnel can be implemented as a chain of **distributed VNFs**
- A chain of VNFs can be dynamically deployed considering specific use-case requirements:
  - Number of tunnels to deploy
  - Number of available links
  - Classifiers (how to aggregate traffic)
  - QoS rules (how to move tunnels)
  - (…)



# Traffic management via QUIC tunnels

- Once the QUIC proxies are deployed, either statically or through a virtualization approach (Orchestration), an overall service operator can manage the whole network resources acting upon
  - The association of a connection to a tunnel (e.g. gold, silver, bronze)
  - The migration of a whole tunnel (for failover, or for opportunity)
- The decision can be based on active measurements realized by the proxy agents (e.g., ping, loss, throughput estimation, etc.), link cost, link availability, user and applications priorities, etc.
- This approach grants the best flexibility in traffic management without requiring lower layer interactions (e.g. SDN).

# Use of the satellite in the global infrastructures

## 5G context

# Use of satellite systems

**Past**

Big ground stations, narrow band, high costs, scarce performance.

**Present**

High throughput satellites (Ka band), small low cost terminals, IP interface, mobility. Innovations on transport protocols (TCP Noordwijk, TCP Wave) or applications (SPDY) reduced the difference between performance of a terrestrial network and a satellite one. Used for high definition video contribution.

**Future**

**Determination of the traffic profile to correctly dimension and efficiently manage the necessary bandwidth (important service identification)**
**Protocol optimization to maximize performance**
**Development of functions compliant with 5G specifications aiming to full use. Seamless security.**
**With architectures based on very efficient heterogeneous networks innovative real time services control linked to the position can be imagined.**
**Small and micro satellite constellations**

# The advent of 5G

| Generation | Technology |
|---|---|
| 1 | Analogue |
| 2 | Digital, circuit switching, narrow band (GSM) |
| 3 | Digital, circuit and IP packet switching, wide band (UMTS) |
| 4 | Larger bandwidth and data rate (LTE) |
| 5 | Larger bandwidth, SDN, NFV, lower power consumption, billions of connections |

**Changes** → **KPIs**

1. **compute and storage services provision**
   - distributed computer, with processes and applications dynamically created, moved, deleted
2. **explosion of IoT and M2M comms**
   - effective authentication, naming, addressing, routing and related functions for a vast number and kind of terminals
3. **vertical sectors (Automotive, Industry 4.0, Entertainment, Energy and E-health)**
   - transport and computing services as virtual distributed computers under complex SLAs

- 1000 times higher mobile data volume per geographical area.
- 10 to 100 times more connected devices.
- 10 to 100 times higher typical user data rate.
- 10 times lower energy consumption.
- End-to-End latency of < 5ms.
- Location precision < 3m
- Mobile speed up to 500 km/h
- Ubiquitous 5G access including low density areas.

# 5G development: Key Concepts

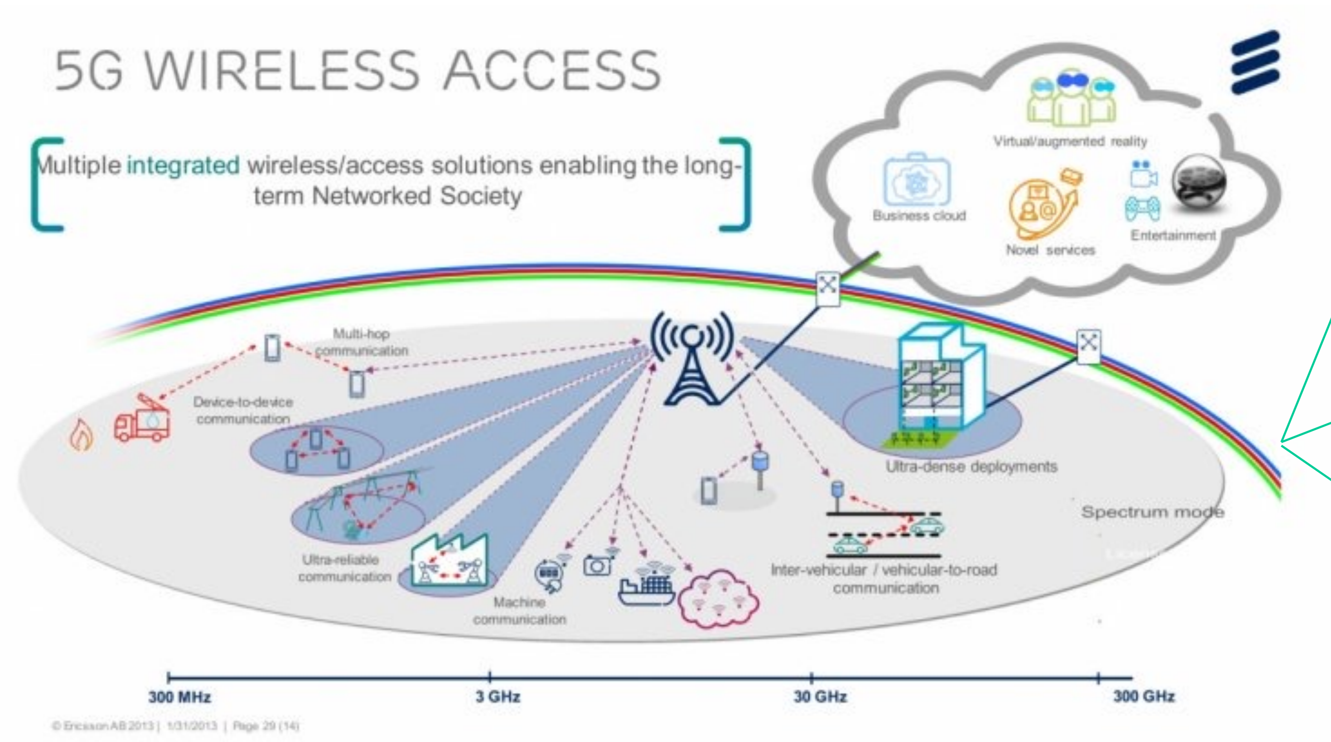
- Network as a service
- Slice
- Software Defined Networking
- Network Function Virtualization
- Orchestration

- Mobile Edge Computing
- Fog Computing
- Softwarization
- Autonomic management
  Cognitive management
- Sustainability
- Micro segmentation

# 5G deployment: action plan

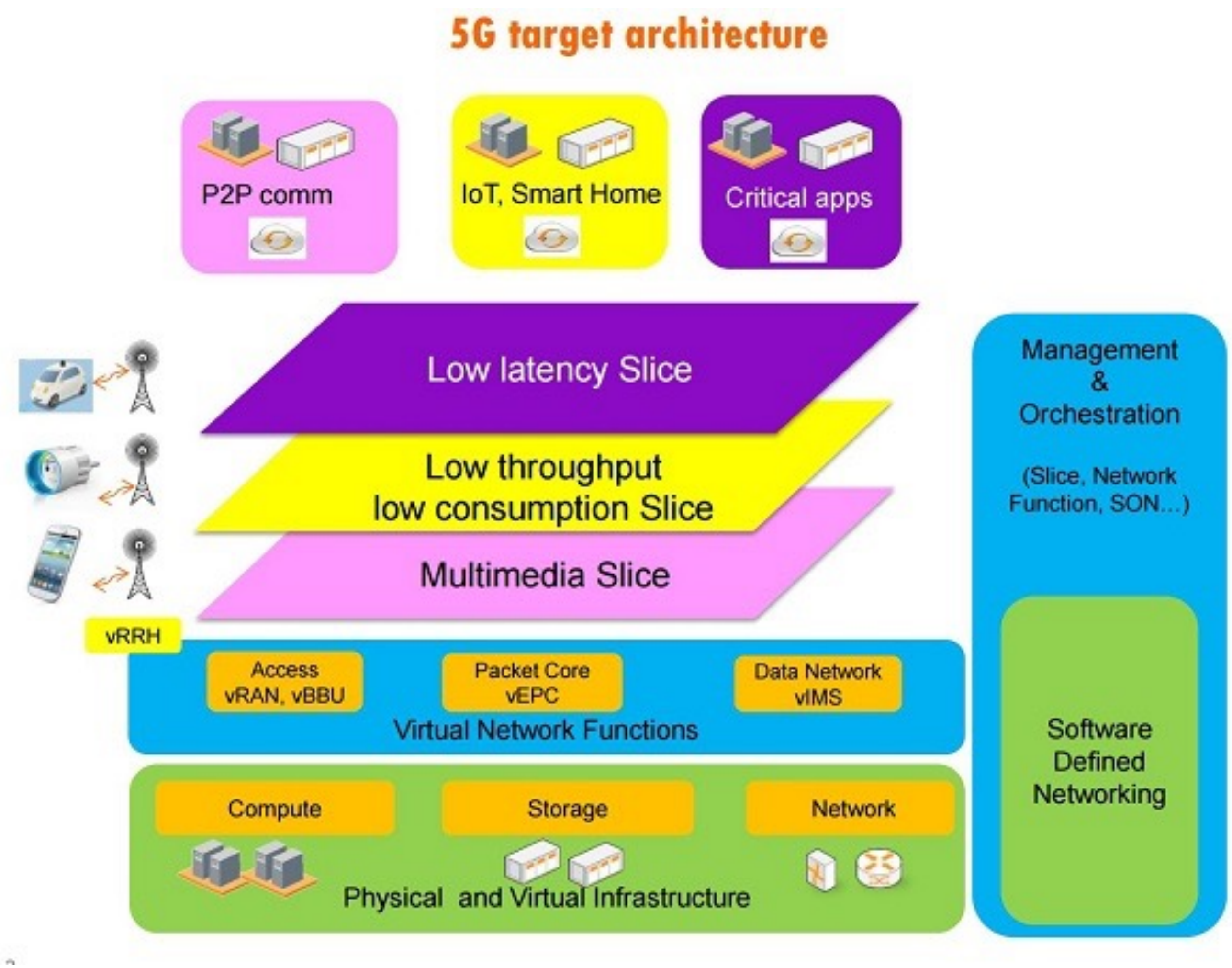
2025 deadline to cover big cities and **transport infrastructures**

# 5G ultra-fast and global wireless access technology





# 5G target architecture



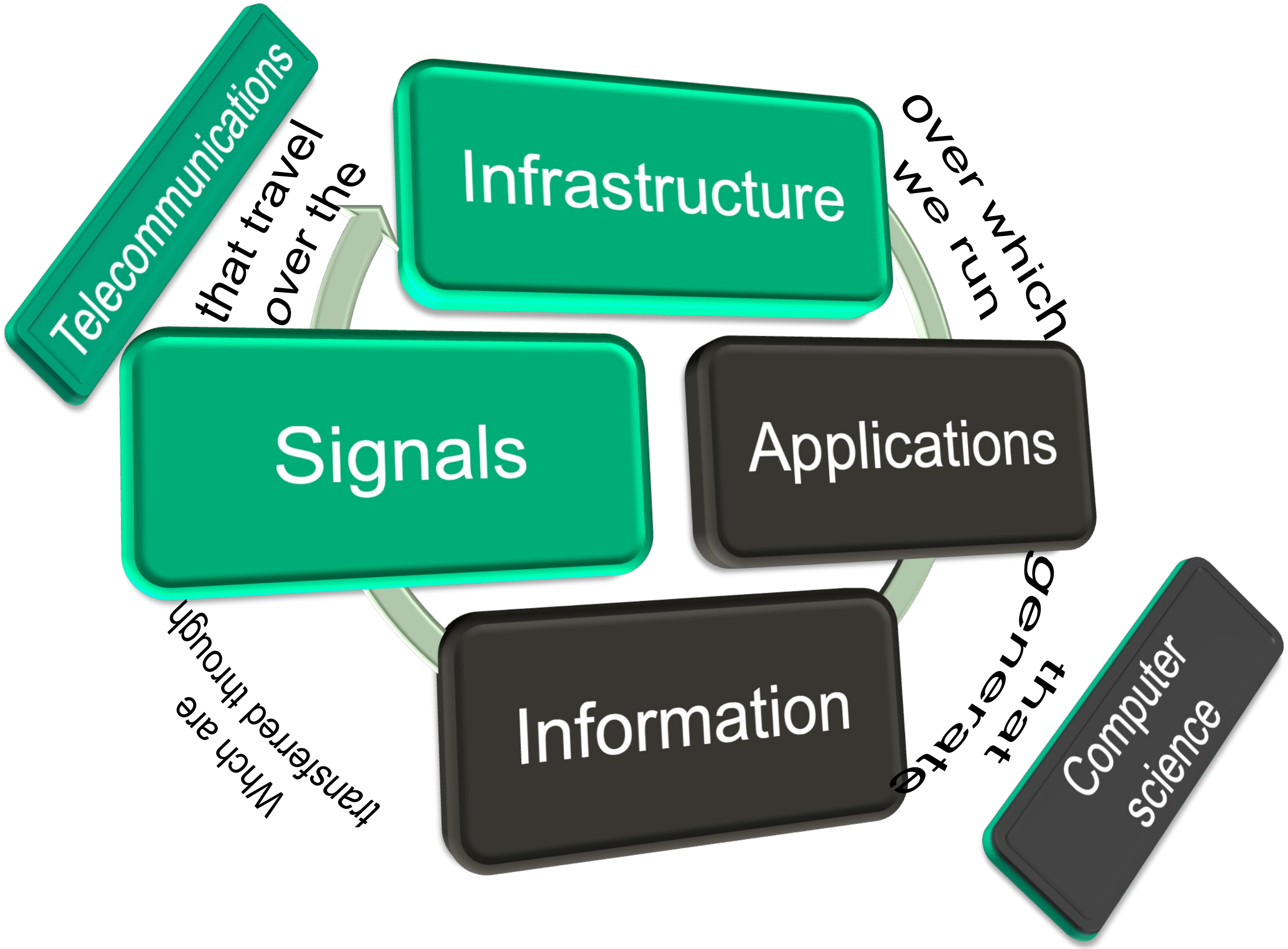
# Use case categories

- Enhanced Mobile Broadband (eMBB)
- Massive Machine Type Communications (mMTC) → 5G terminology to refer **IoT** of previous standards
- Ultra Reliable and Low Latency Communications (URLLC)

| Requirement | Required value |
|---|---|
| **Latency, user plane** | 1 ms for URLLC |
| **Latency, control plane** | 20 ms |
| **Connection density** | 1 000 000 devices / $km^2$ |
| **Reliability** | 99.999% success rate within 1 ms |
| **Mobility interruption time** | 0 ms |
| **Throughput (peak)** | 20 Gbit/s (DL) - 10 Gbit/s (UL) |
| **Mobility** | 500 km/h (0.45 bit/s/Hz) |
| **Latency, user plane** | 4 ms for eMBB |

**URLLC requirement**
**mMTC requirement**
**eMBB requirement**

# Internet components



# Role of Satellite for the 5G

- Drivers for 5G
  - User demand mobile data growth (1 Gbit/s)
  - Smarter/flexible networks – *virtualisation, SDN, Dense networks with smaller cells, area spectral efficiency needs to be increased by an order of magnitude*
  - Spectrum sharing – mix of licenced and unlicenced
  - Lower energy by 90%
  - Internet of Things, billions of objects connected (big data)
  - More resilient & secure systems at no extra cost improving QoE.

- Satellite role in 5G
  - Coverage air, sea and remote areas- extending terrestrial mobile networks.
  - Services broadcast and **multicast**. Cloud services and bulk downloads.
  - Integrated approach taking the load off the terrestrial network (particularly video); ICN/CDN—optimum deliver services with novel combinations—integrated standards
  - Backhaul – providing flexibility of higher rate backhaul and the control overlay cell in a heterogeneous network. Integration with 5G core network
  - Flexibility – High uplink data rate on demand or when needed

# Why to use satellite?

- Costs independent on distance (within one satellite coverage)
- Collecting and broadcasting characteristics
- Particularly suitable and cost effective for multicasting
- Irreplaceable in areas with scarce or no infrastructures
- Irreplaceable in case of disaster
- Suitable for large coverage areas and long range mobility
- Relatively short deployment time
- Flexible architecture
- Bypass very crowded terrestrial networks
- With the same infrastructure both fixed and mobile services

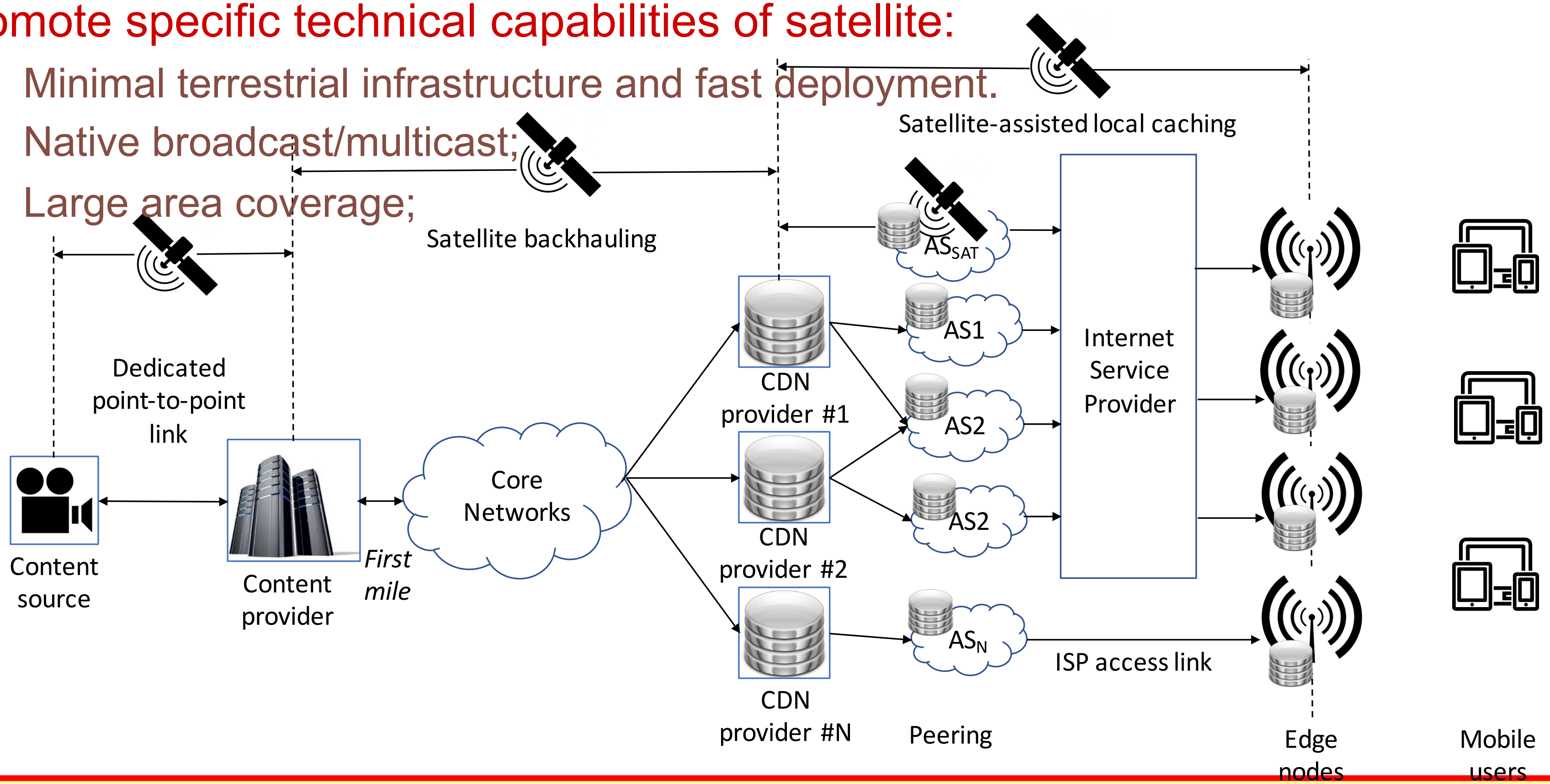
- Disruptive to feed CDN nodes
- Efficient to distribute security keys

From being a problem due to delay

to being the element that can meaningfully contribute to achieve the "zero latency" and to efficiently face the multi-domain issue

# 5G satellite role for streaming-based vision

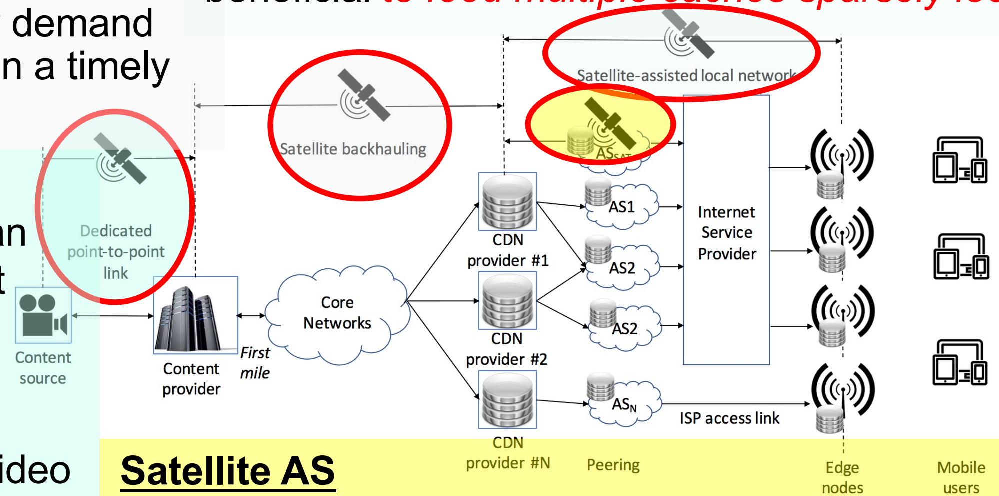
- Satellite role can be multiple over the end-to-end communication path, bringing advantages at different levels
- High Throughput Satellite (HTS) platforms reduced cost per bit generating greater opportunity for satellite industry, which can better promote specific technical capabilities of satellite:
  - Minimal terrestrial infrastructure and fast deployment.
  - Native broadcast/multicast;
  - Large area coverage;



**Satellite backhauling links:**
Content provider could offload video flows over a satellite link to either avoid possible congestion in the “first mile” connection to the core networks or *counteract asymmetry of terrestrial access* network or *exploit an efficient multicast distribution* to multiple Content Delivery Network (CDN) providers.
The most popular large-scale video content providers (e.g. YouTube, Netflix) must face up a heavy demand on Internet bandwidth to offer their services in a timely manner.

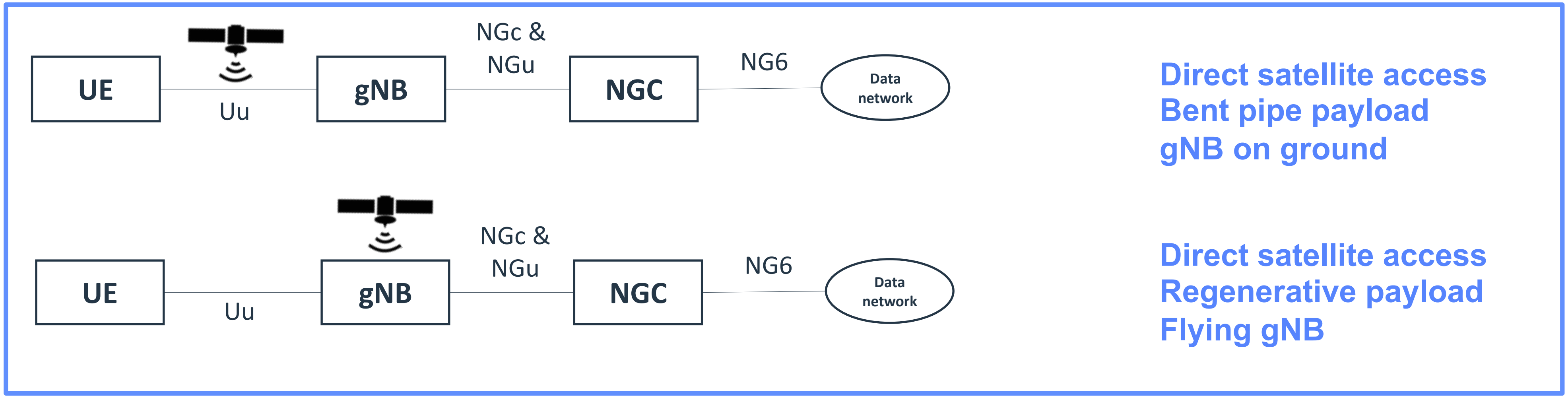
**Satellite assisted local network**
Current access networks leverage on Autonomous Systems (AS), which represent the unique administrative entity to manage IP services and interconnect the access network with the other networks. AS can implement local capabilities to enhance user experience. An example is the local caching. In this concern, the satellite can be beneficial *to feed multiple caches sparsely located*.

**Dedicated point-to-point links:**
Starting from the content creation, satellite can play a role in the connection between content source and content provider premises (e.g. server farm).
Currently, dedicated satellite links are largely adopted as *contribution segment* in case of video streaming for live TV transmissions.
In general, content source and content provider are not co-located and need dedicated links.

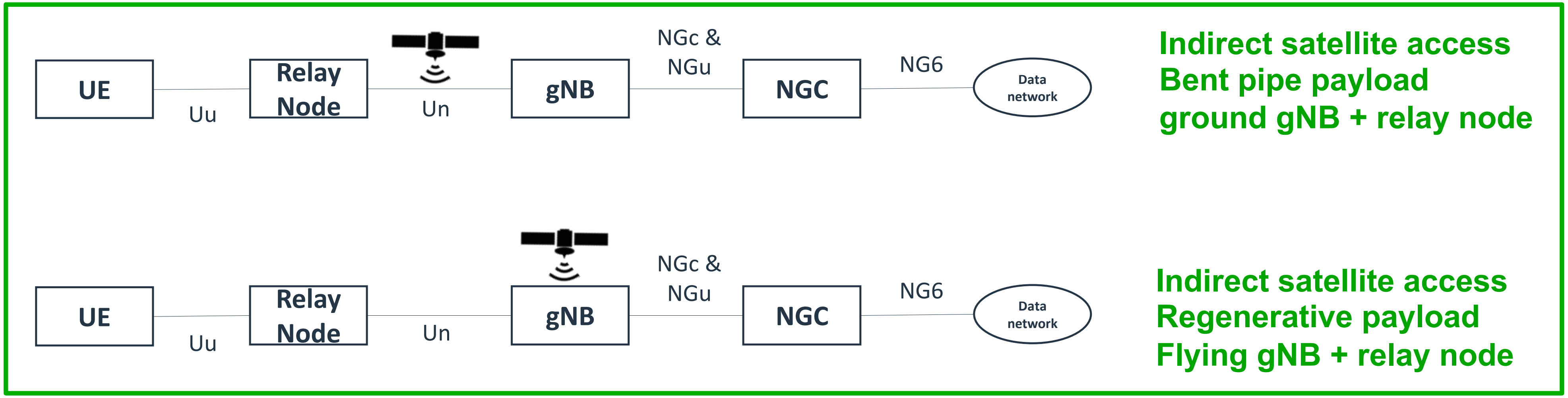



**Satellite AS**
A satellite network can represent itself an AS ($AS_{SAT}$). An AS could be the network of an Internet Service Provider (ISP), while an ISP could leverage on multiple ASs (e.g. acting as an Over-the-Top – OTT – player).

# NTN Architecture Options (3GPP TR38.811)

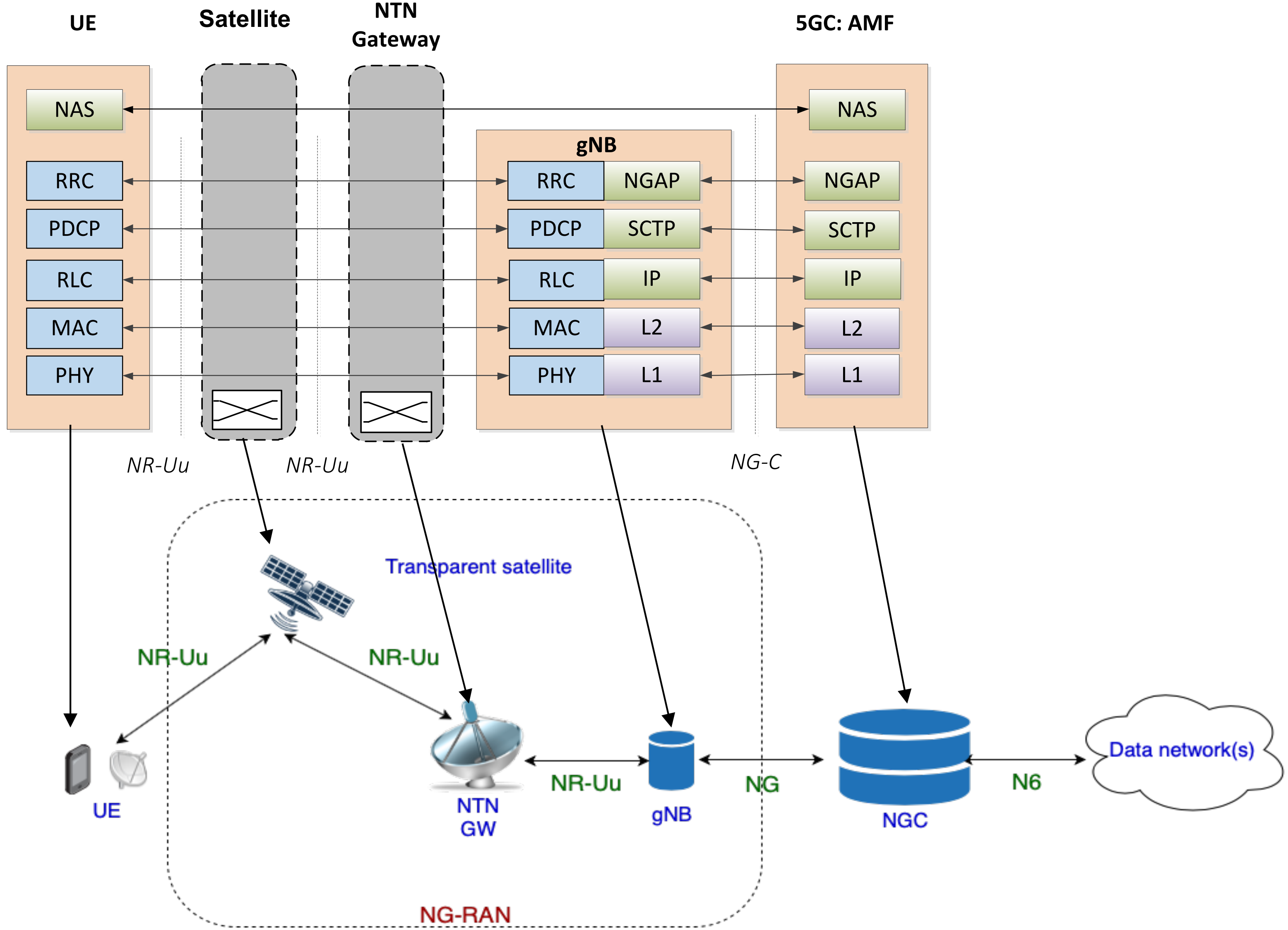



NTN = Non Terrestrial Networks



# NTN Architecture Options: Direct access

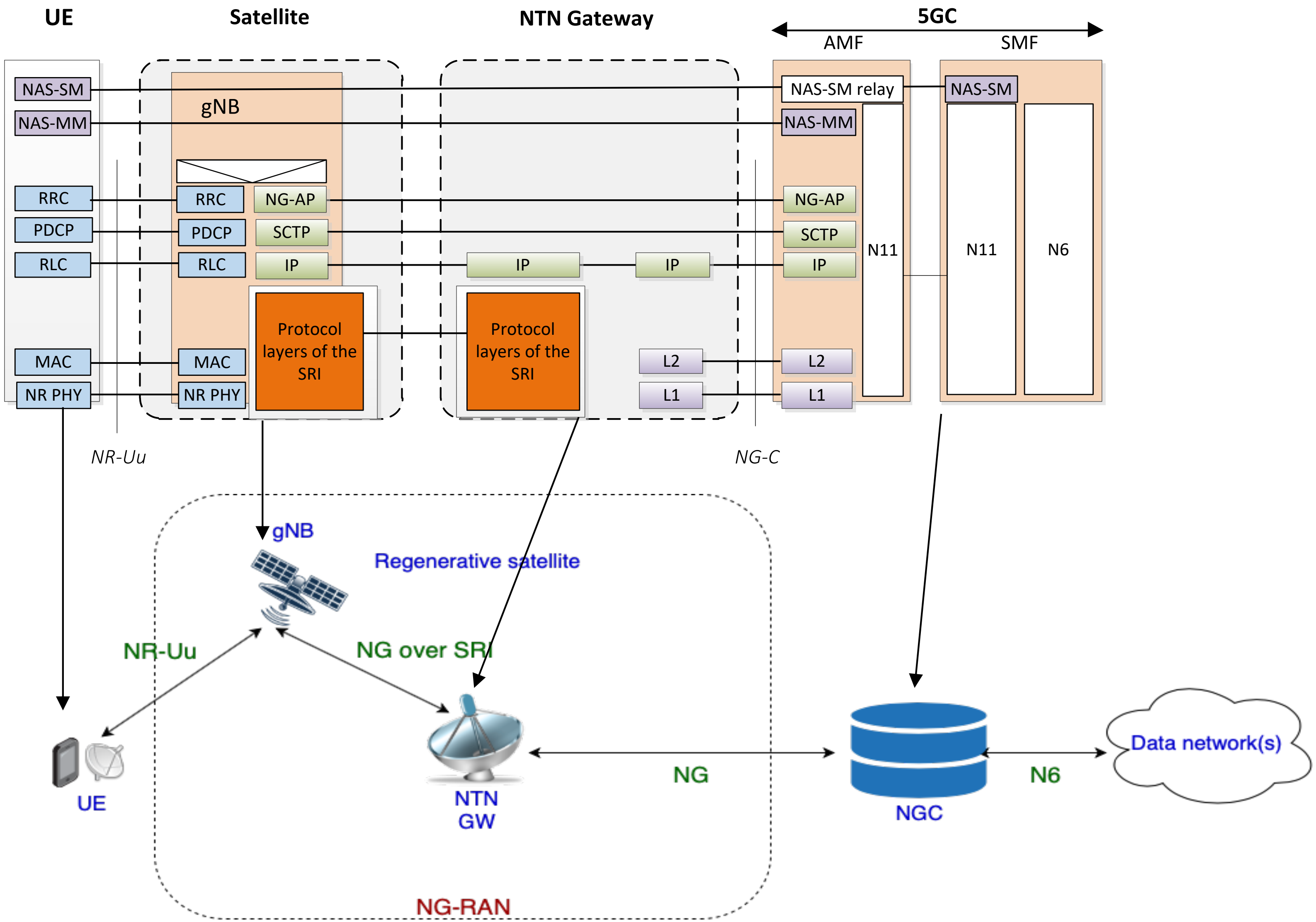
**Transparent Payload**




*Source: TR 38.821*

# NTN Architecture Options: Direct access

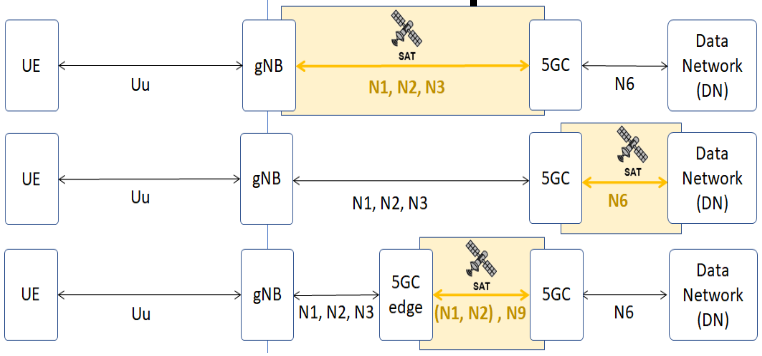
**Regenerative Payload**

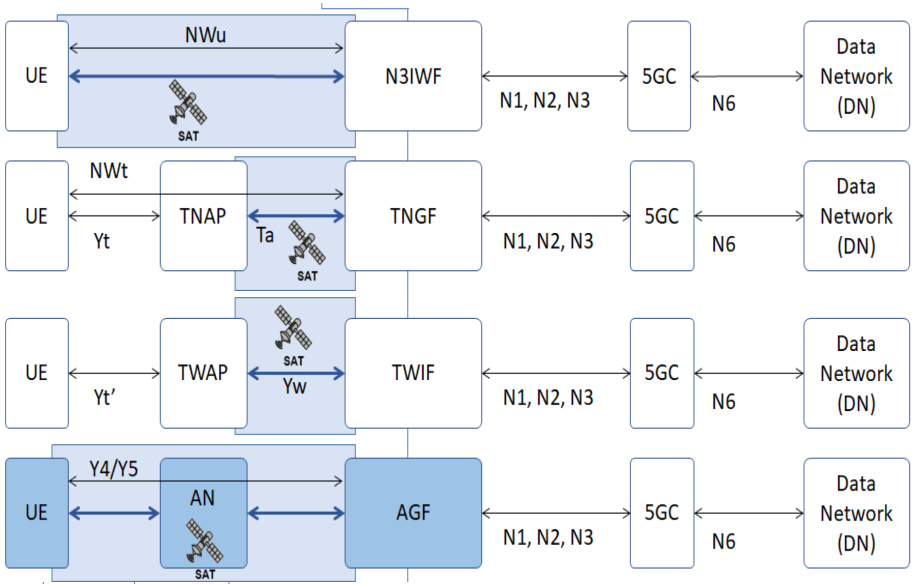



Source: TR 38.821

# NTN Integration Modes

## Backhaul & Transport




## Non3GPP Access

## Direct Access