PENGEMBANGAN MUTAKHIR

Ref : Ha Yoon Song, David Ball

HAPS

- High Altitude Platforms(HAPs)
- Stratospheric Platforms(SPFs)
- Height 17 ~ 22Km
- from hot-air balloons

- Advantage of
- Satellite Communication System
- Terrestrial Wireless System

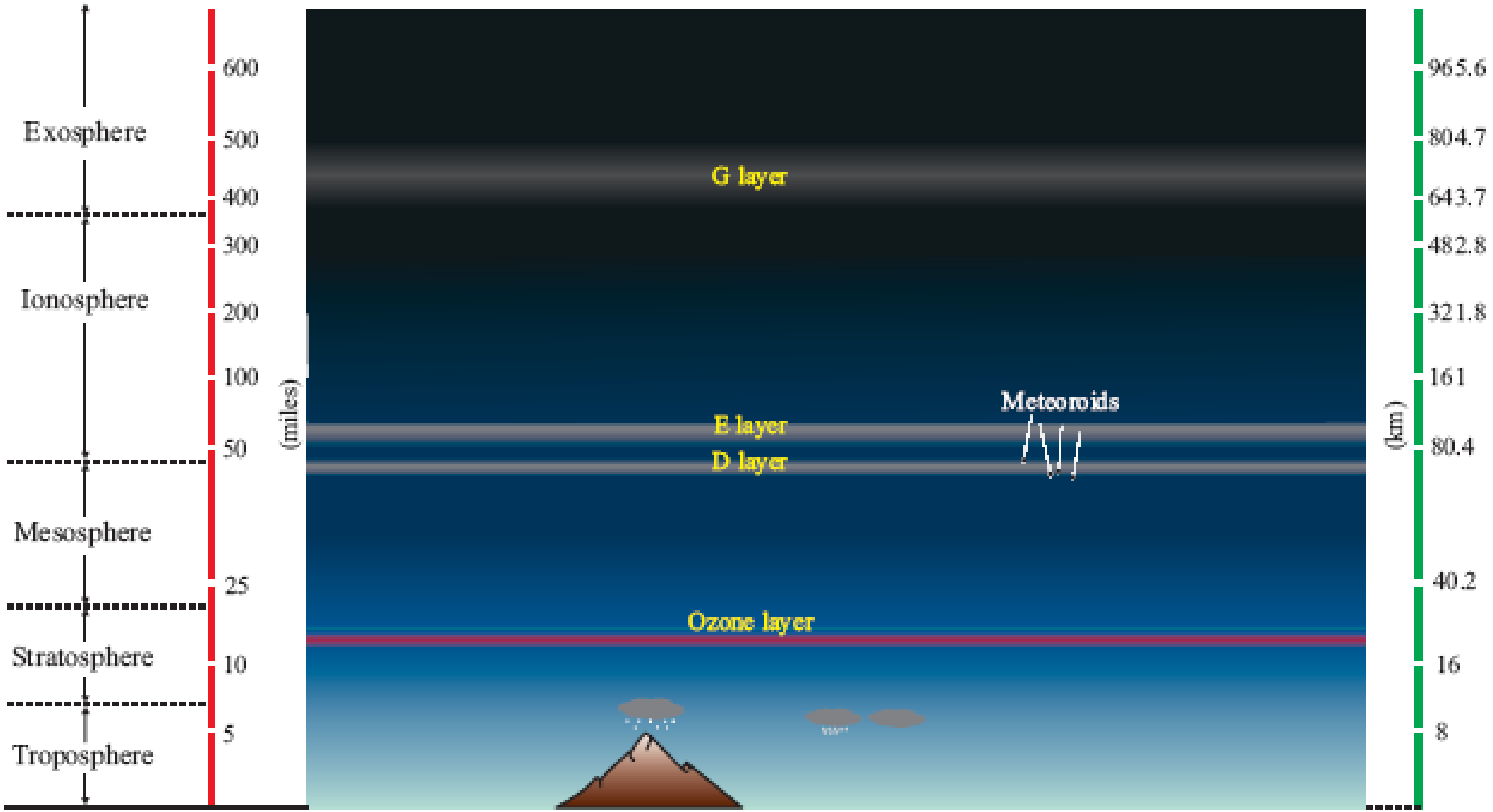


Fig. 1. The Atmosphere Layers

Table I. Basic characteristics of Terrestrial Wireless, Satellite and HAPs systems

Issue	Terrestrial Wireless	Satellite	High Altitude Platform
Availability and cost of mobile terminals	Huge cellular/PCS market drives high volumes resulting in small, low-cost, low-power units	Specialized, more stringent requirements lead to expensive bulky terminals with short battery life	Terrestrial terminals applicable
Propagation delay	Low	Causes noticeable impairment in voice communications in GEO (and MEO to some extend)	Low
Health concerns with radio emissions from handsets	Low-power handsets minimize concerns	High-power handsets due to large path losses (possibly alleviated by careful antenna design)	Power levels like in terrestrial systems (except for large coverage areas)
Communications technology risk	Mature technology and well-established industry	Considerably new technology for LEOs and MEOs; GEOs still lag behind cellular/PCS in volume, cost and performance	Terrestrial wireless technology, supplemented with spot-beam antennas; if widely deployed, opportunities for specialized equipment (scanning beams to follow traffic)
Deployment timing	Deployment can be staged, substantial initial build-out to provide sufficient coverage for commercial service	Service cannot start before the entire system is deployed	One platform and ground support typically enough for initial commercial service
System growth	Cell-splitting to add capacity, requiring system reengineering: easy equipment upgrade/repair	System capacity increased only by adding satellites; hardware upgrade only with replacement of satellites	Capacity increase through spot-beam resizing, and additional platforms; equipment upgrades relatively easy
System complexity due to motion of components	Only user terminals are mobile	Motion of LEOs and MEOs is a major source of complexity, especially when intersatellite links are used	Motion low to moderate (stability characteristics to be proven)
Operational complexity and cost	Well-understood	High for GEOs, and especially LEOs due to continual launches to replace old or failed satellites	Some proposals require frequent landings of platforms (to refuel or to rest pilots)

Radio channel "quality"	Rayleigh fading limits distance and data rate, path loss up to 50 dB/decade; good signal quality through proper antenna placement	Free-space-like channel with Ricean fading; path loss roughly 20 dB/decade; GEO distance limits spectrum efficiency	Free-space-like channel at distances comparable to terrestrial
Indoor coverage	Substantial coverage achieved	Generally not available (high-power signals in Iridium to trigger ringing only for incoming calls)	Substantial coverage possible
Breadth of geographical coverage	A few kilometres per base station	Large regions in GEO (up to the 34% of the earth surface); global for LEO and MEO	Hundreds of kilometres per platform (up to 200km)
Cell diameter	0.1 – 1 km	50km in the case of LEOs. More than 400km for GEOs	1 – 10 km
Shadowing from terrain	Causes gaps in coverage; requires additional equipment	Problem only at low elevation angles	Similar to satellite
Communications and power infrastructure; real estate	Numerous base stations to be sited, powered, and linked by cables or microwaves	Single gateway collects traffic from a large area	Comparable to satellite
Esthetic issues and health concerns with towers and antennas	Many sites required for coverage and capacity; "smart" antennas might make them more visible; continued public debates expected	Earth stations located away from populated areas	Similar to satellite
Public safety concern about flying objects	Not an issue	Occasional concern about space junk falling to Earth	Large craft floating or flying overhead can raise significant objections
Cost	Varies	More then $200 million for a GEO system. Some billion for a LEO system (e.g. $5 billion for Iridium, $9 billion for Teledesic)	Unspecified (probably more than $50 million), but less than the cost required to deploy a terrestrial network with many base stations

HAPS

- Easy to deploy, incremental deploy
- Flexibility, Reconfigurability
- Low cost of operation (comparing to Satellites)
- Low propagation delay
- High Elevation!
- Wide area coverage
- Broadcast/Multicast
- Mobility !

- BUT, Problems with
- Monitoring of Station
- Airship manufacturing
- Antenna technology

HAPS

- HAPs for 3G + system because of
  - Easy to maintain
  - Easy to deploy
  - Lower path loss

- 4G : Satellite + HAPS = MBMS (Multimedia Broadcast and Multicast Services).

- Stand alone HAPs for low population with large area.

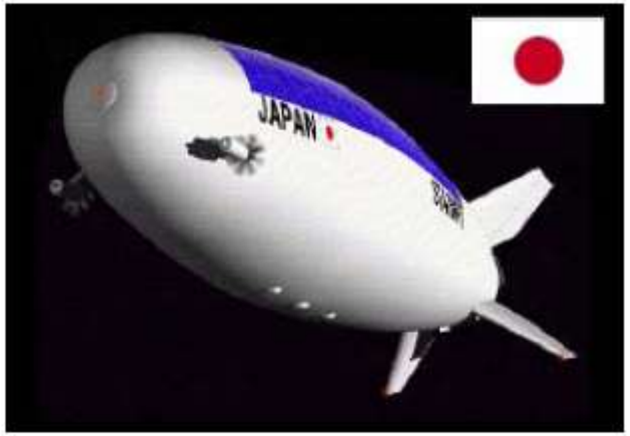
Aerial Vehicles, Key Issues and Spectrum Allocation

- Three types

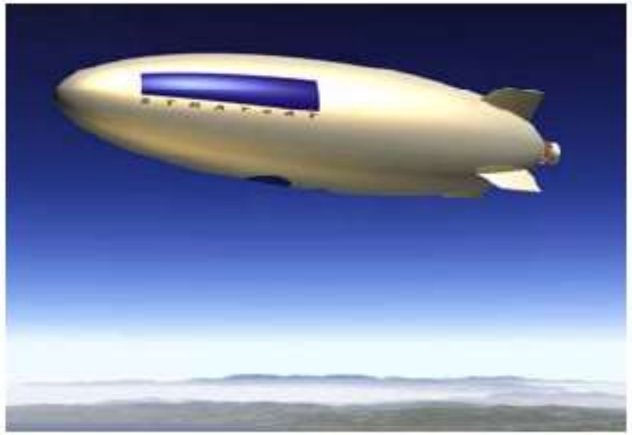
1) Propulsion + unmanned airships(balloons, aerostats)

2) High Altitude Long Endurance Platforms (HALE Platforms)
   Solar-powered unmanned aircraft

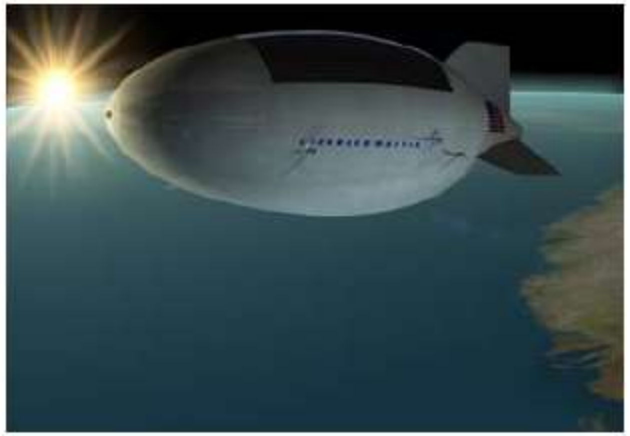
3) Manned aircraft(???)



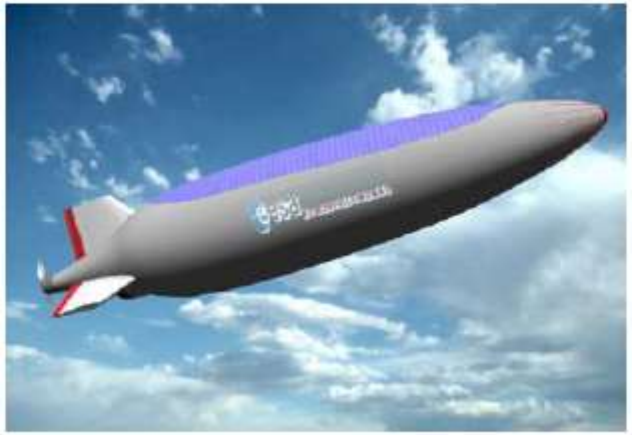
NAL "SPF" (Stratospheric PlatForm) (JAPAN)



ATG "StratSat" (UK)



Lockheed Martin NESS (US)



European Space Agency (ESA)

Fig. 2. Solar-powered unmanned Airships

AeroVironment /NASA
"HELIOS" (US)
Wingspan: 75m
Payload: 50 -100kgr

AeroVironment /NASA
"Pathfinder Plus" (US)
Wingspan: 36.9m
Payload: 50 kgr

HELINET project Heliplat
(Artist's Impression)
(Politecnico di Torino)
Wingspan: 70m
Payload: 100kgr

Fig. 3. Solar-powered unmanned Aircraft

Angel Technologies HALO (Proteus 9)
Manned aircraft for the delivery of communication services

M-55 stratospheric aircraft (Geoscan Network)
Piloted aircraft for the delivery of wireless services and remote sensing

Fig. 4. Manned Aircraft

Table II. A general comparison among Airships, Solar-powered unmanned Aircraft and manned Aircraft

	Airships (unmanned)	Solar-powered unmanned Aircraft	Manned Aircraft
Size	Length 150 ~ 200 m	Wingspan 35 ~70 m	Length ≈30 m
Total weight	≈ 30 ton	≈ 1 ton	≈ 2.5 ton
Power source	Solar cells (+Fuel cells)	Solar cells (+Fuel cells)	Fossil Fuel
Environmentally friendly	✓	✓	✗
Response in Emergency situations	✗	✓	✓
Flight duration	Up to 5 years	Unspecified (≈ 6 months)	4 - 8 hours
Position Keeping (radius)	Within 1 km cube	1 - 3 km	≈ 4 km
Mission payload	1000 ~ 2000 kg	50 ~ 300 kg	up to 2000 kg
Power for mission	≈ 10 kW	≈ 3 kW	≈ 40 kW
Example	Japan, Korea, China, ATG, Lockheed Martin, SkyStation etc.	Helios, Pathfinder Plus (AeroVironment), Heliplat (European project)	HALO (Angel Technologies) M-55 (Geoscan Network)

Global Hawk (US)
Altitude: 65,000 feet
Speed: 454 mph

Predator (US)
Altitude: 25,000 feet
Speed: 135 mph

Fig. 5. Unmanned fuelled Aircraft

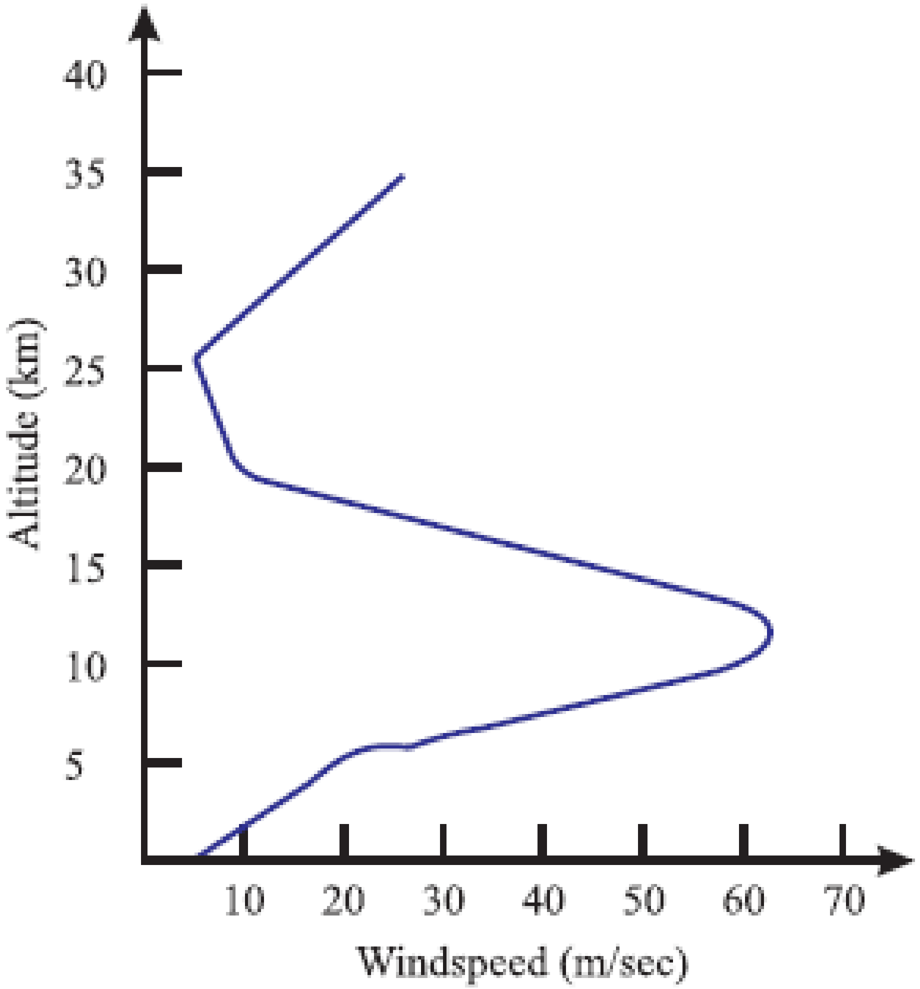


Fig. 6. Wind velocity with respect to the altitude *(this is a redrawn version of the figure that appeared in [14])*

Table V. Current frequency bands allocated for communications via HAPs

Frequency Band	Areas	Direction of the link	Services	Services to be shared with
47.9-48.2 GHz 47.2-47.5 GHz	Global	Up and downlinks	Fixed service	Fixed and mobile services Fixed satellite service (uplink) Radio astronomy band neighbouring
31.0-31.3 GHz	40 countries worldwide (20 countries in Asia, Russia, Africa, etc and in Region 2)	Uplink	Fixed service	Fixed and mobile services Space science service in some areas Space science service band (passive) neighbouring
27.5-28.35 GHz[1]	40 countries worldwide (20 countries in Asia, Russia, Africa, etc and in Region 2)	Downlink	Fixed service	Fixed and mobile services Fixed satellite service (uplink)
1885-1980 MHz 2010-2025 MHz 2110-2170 MHz	Regions 1 and 3	Up and downlinks	IMT-2000	Fixed and mobile services (in particular, terrestrial IMT-2000 and PCS)
1885-1980 MHz 2110-2160 MHz	Region 2	Up and downlinks	IMT-2000	Fixed and mobile services (in particular, terrestrial IMT-2000 and PCS)

Region 1: Europe, Africa, Russia, the Middle East and Mongolia
Region 2: North and south America
Region 3: Asia except for the Middle East, Pacific countries and Iran

Architectures and Services I-Network Design-

- High reliability
- Low power consumption
- Lighter payload

- Max 150KM footprint by ITU

- Min. 5 degree of elevation
- Recommended 15+ degree to avoid clutter

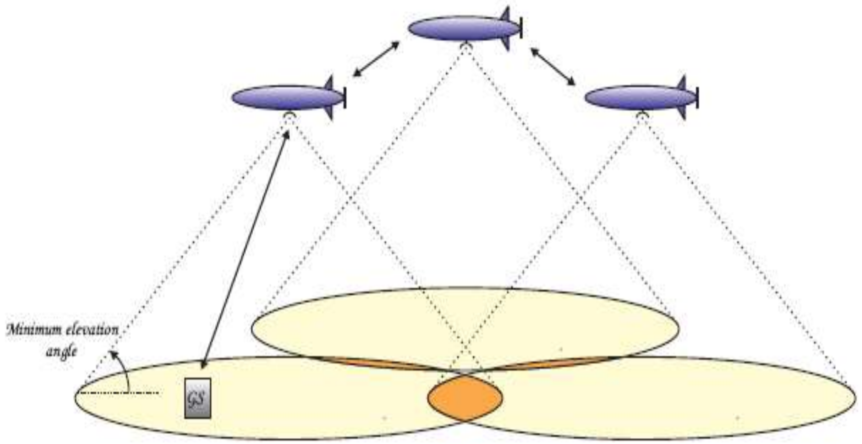


Fig. 8. A General architecture of a HAPs system

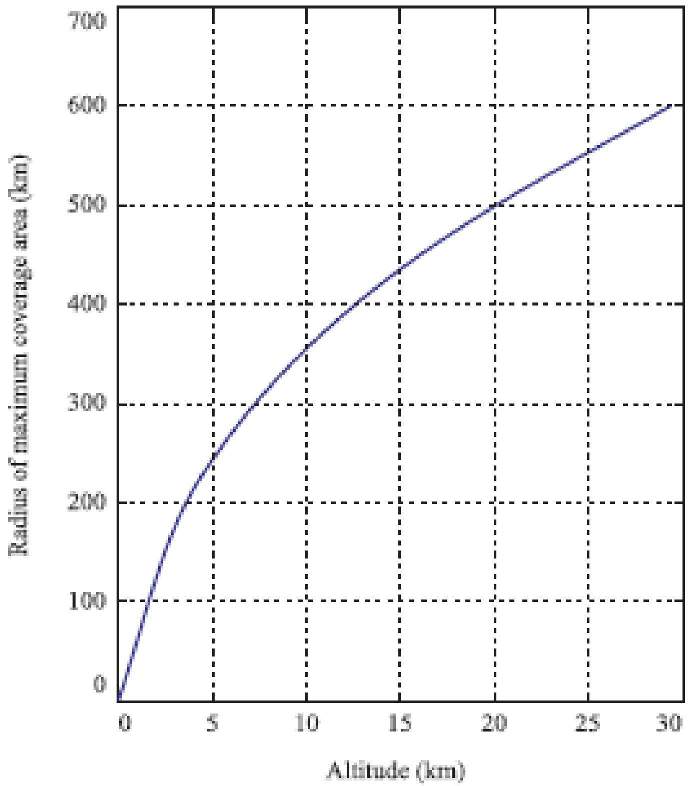


Fig. 9. Radius of the maximum coverage area as a function of the HAP altitude

Architectures and Services(2) -Network Design-

- Frequency Reuse
- Cellular architecture
- High Bandwidth for Broadband application

- Fixed Channel Allocation(FCA)
- Dynamic Channel Allocation(DCA)
-
- HeliNet Network
- CAPANINA

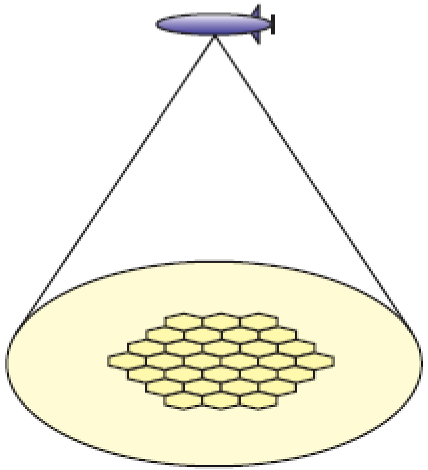


Fig. 10. A Cellular architecture

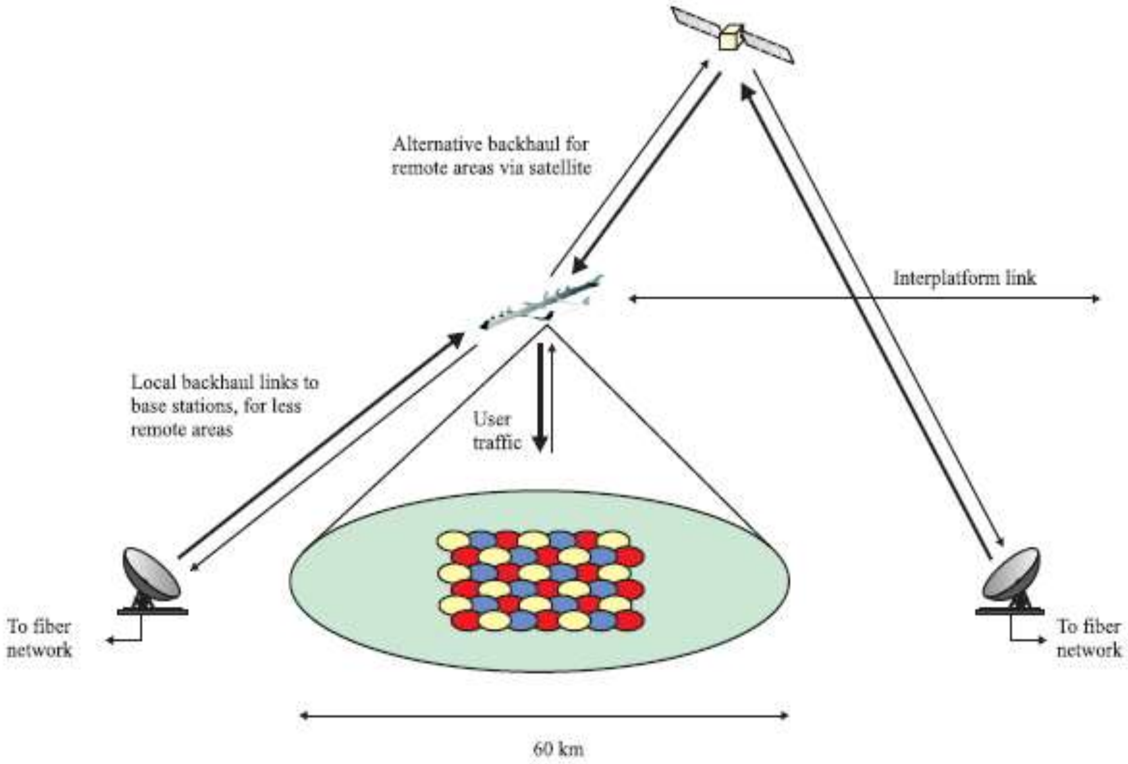


Fig. 11. The architecture scenario of the HeliNet Network

Architectures and Services(3) -Network Design-

- Backhaul links, duplicated

- High traffic for down link
- Asymmetry to uplink
- Multiple uplinks for backhaul station
- Macrocell and microcell architecture (Fig.12)
- Rural macrocell (Fig.13)
- Sectoring. (Fig.14) for system capacity

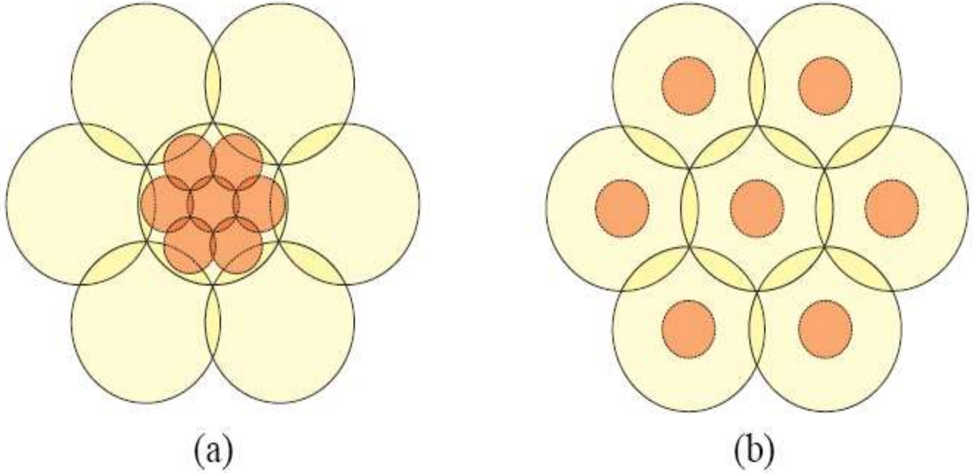


Fig. 12. Cell forming according to traffic

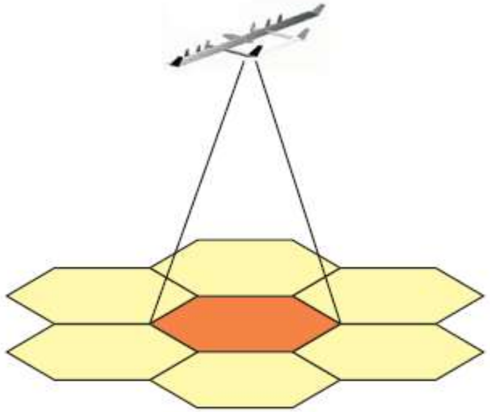


Fig. 13. The aerial cell

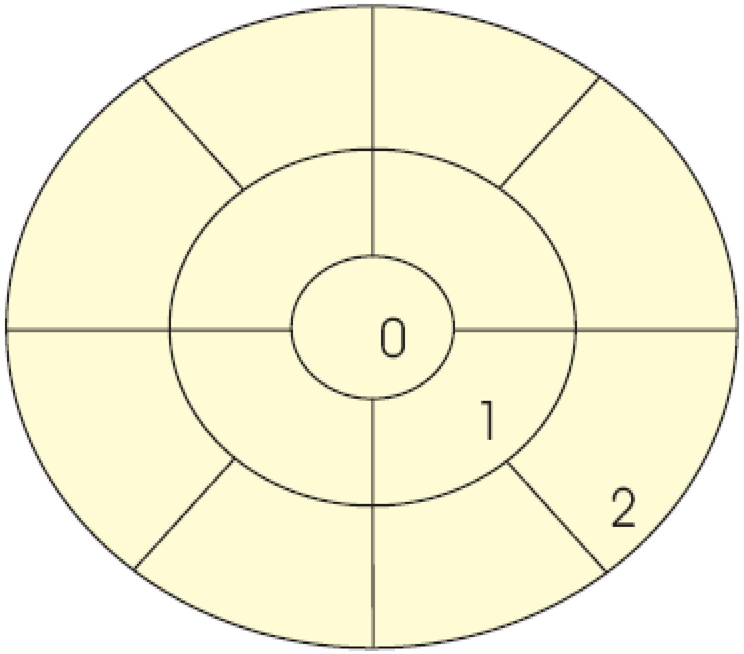


Fig. 14. Example of theoretical sectorization pattern with two outer circles

Architectures and Services(5) -Network Design-

- Ring-shaped Cell Clustering (Fig. 15).
- Coaxial Rings
- Multi-beam, controllable antenna
- Simpler handoff design

- Cell scanning (Fig. 16)

- Stratospheric radio-relay Maritime (Fig.17)

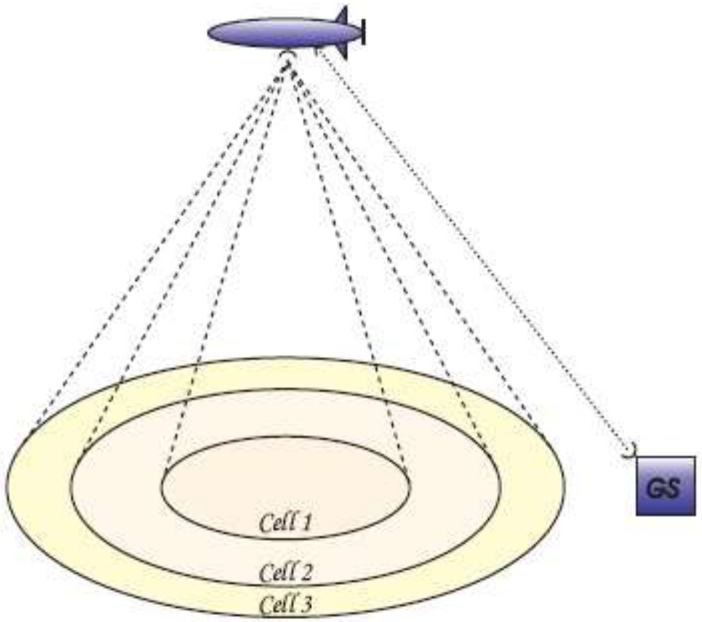


Fig. 15. Ring-shaped Cells

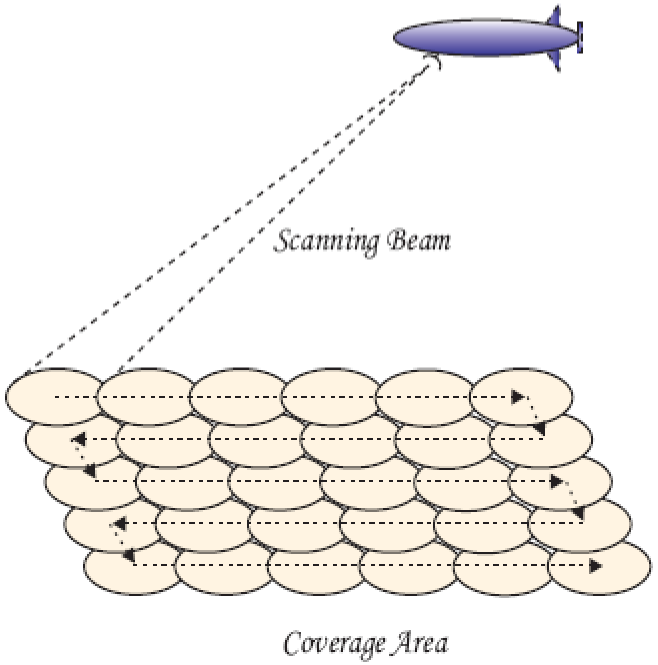


Fig. 16. Cell scanning

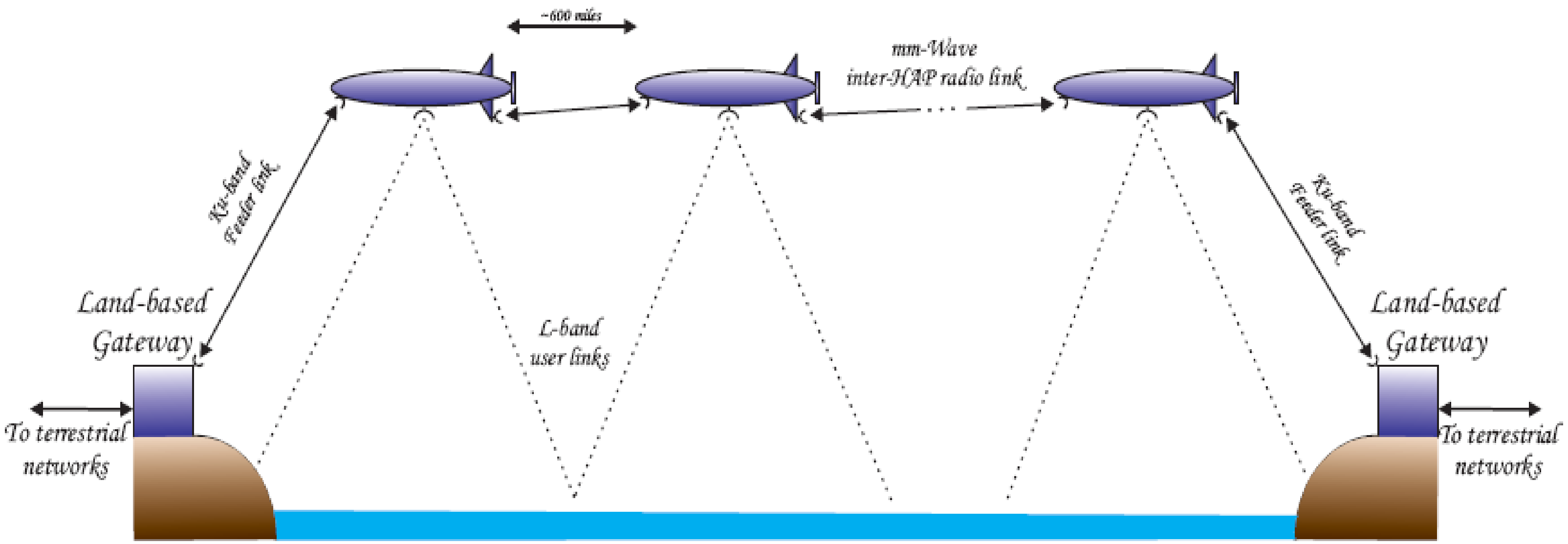


Fig. 17. A HAPs-based system for maritime services

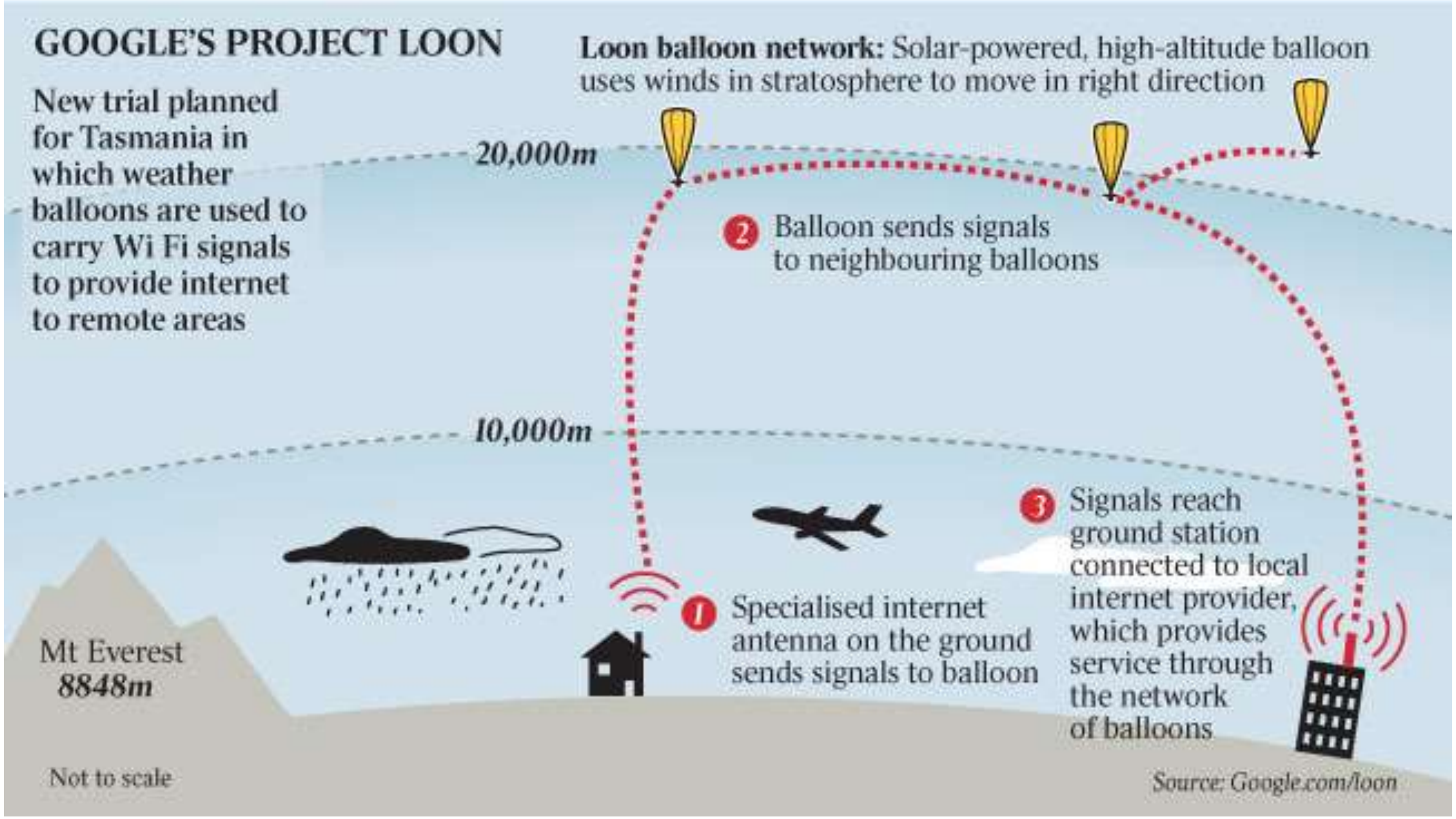
Antennas(1)

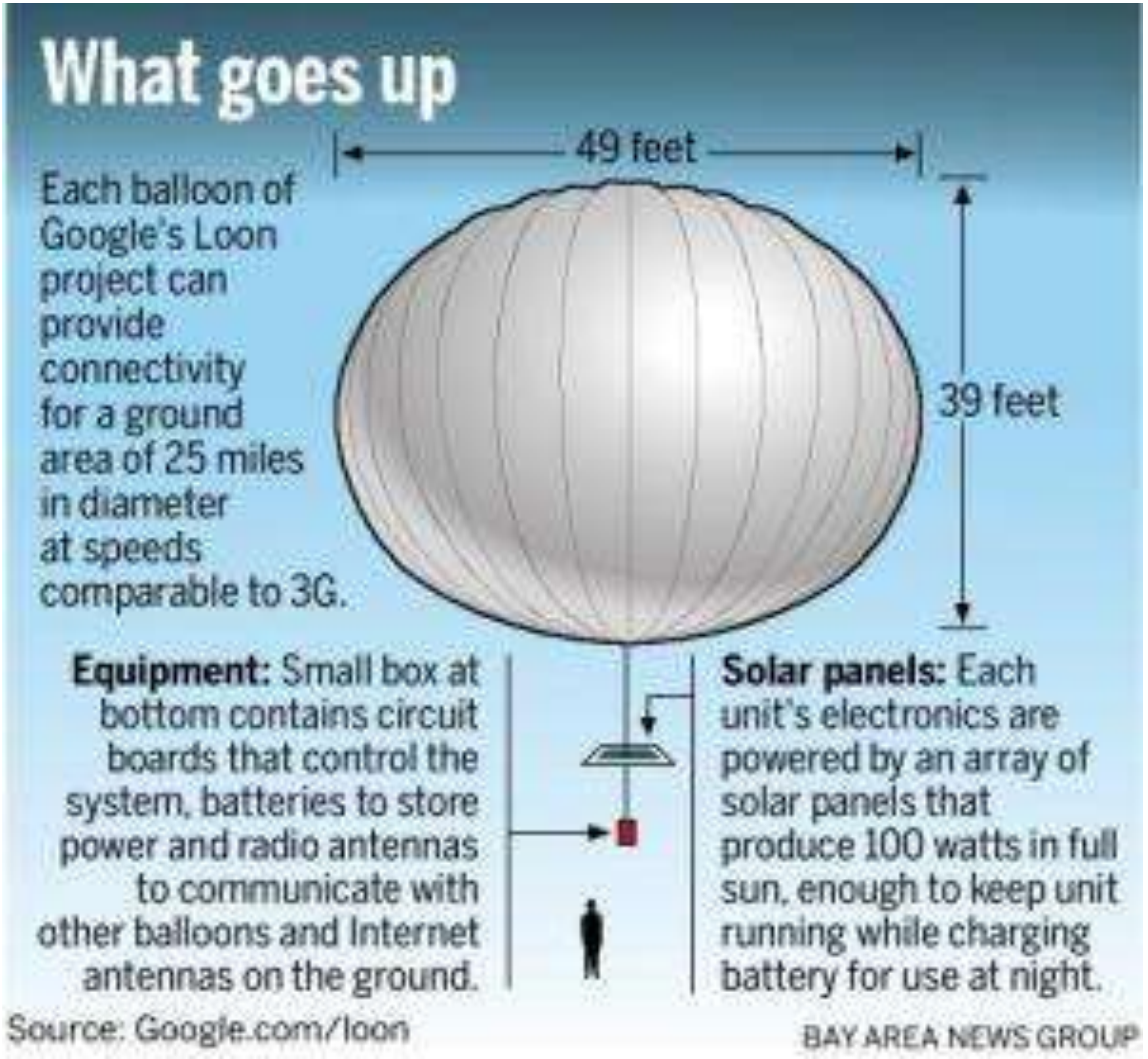
- Requirements

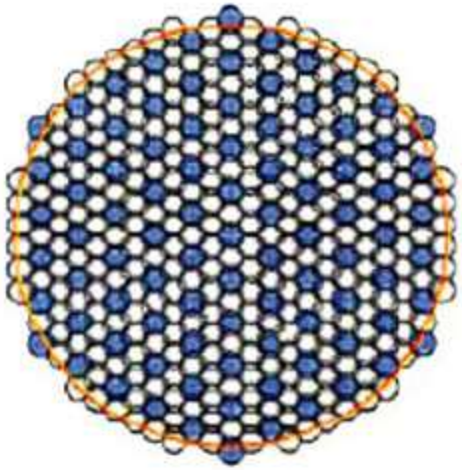
1. High frequency for High bandwidth
2. High gain, directional antenna
3. Multibeam antenna with 100+ beams
4. Fig. 34 for footprint
5. Beam controllability
6. Low payload and low power
7. Reliability

Antennas(2)

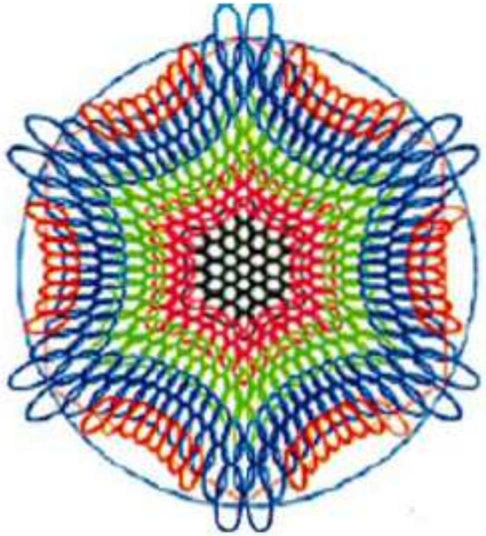
- Array of the antenna at 2.2Ghz, 21Km height
- Wider array with high altitude, narrower array with high frequency
- Multibeam Horn(MBH)
- Digital Beamforming(DBF)
- Table XⅡ


GOOGLE'S PROJECT LOON
New trial planned for Tasmania in which weather balloons are used to carry Wi Fi signals to provide internet to remote areas
Loon balloon network: Solar-powered, high-altitude balloon uses winds in stratosphere to move in right direction
20,000m
2 Balloon sends signals to neighbouring balloons
10,000m
3 Signals reach ground station connected to local internet provider, which provides service through the network of balloons
1 Specialised internet antenna on the ground sends signals to balloon
Mt Everest 8848m
Not to scale
Source: Google.com/loon


What goes up
49 feet
39 feet
Each balloon of Google's Loon project can provide connectivity for a ground area of 25 miles in diameter at speeds comparable to 3G.
Equipment: Small box at bottom contains circuit boards that control the system, batteries to store power and radio antennas to communicate with other balloons and Internet antennas on the ground.
Solar panels: Each unit's electronics are powered by an array of solar panels that produce 100 watts in full sun, enough to keep unit running while charging battery for use at night.
Source: Google.com/loon
BAY AREA NEWS GROUP



(a)



(b)

Fig. 34. Typical examples of multibeam footprints proposed in the ITU-R recommendation. (a) Elliptical-beam uniform footprint model (367 beams). (b) Circular-beam Multizone footprint model (397 beams).

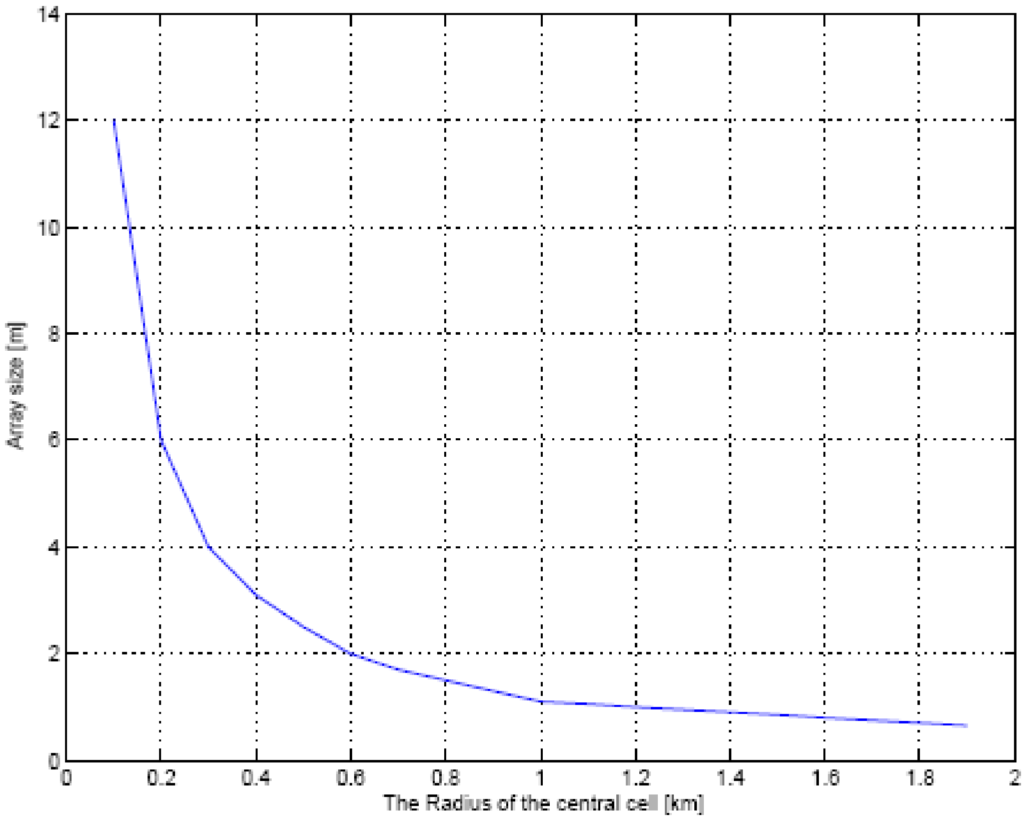


Fig. 35. The size of a square array antenna as a function of the radius of the central cell for a HAP operating at 2.2 GHz and at an altitude of 21km *(this is a redrawn version of the figure that appeared in [9])*

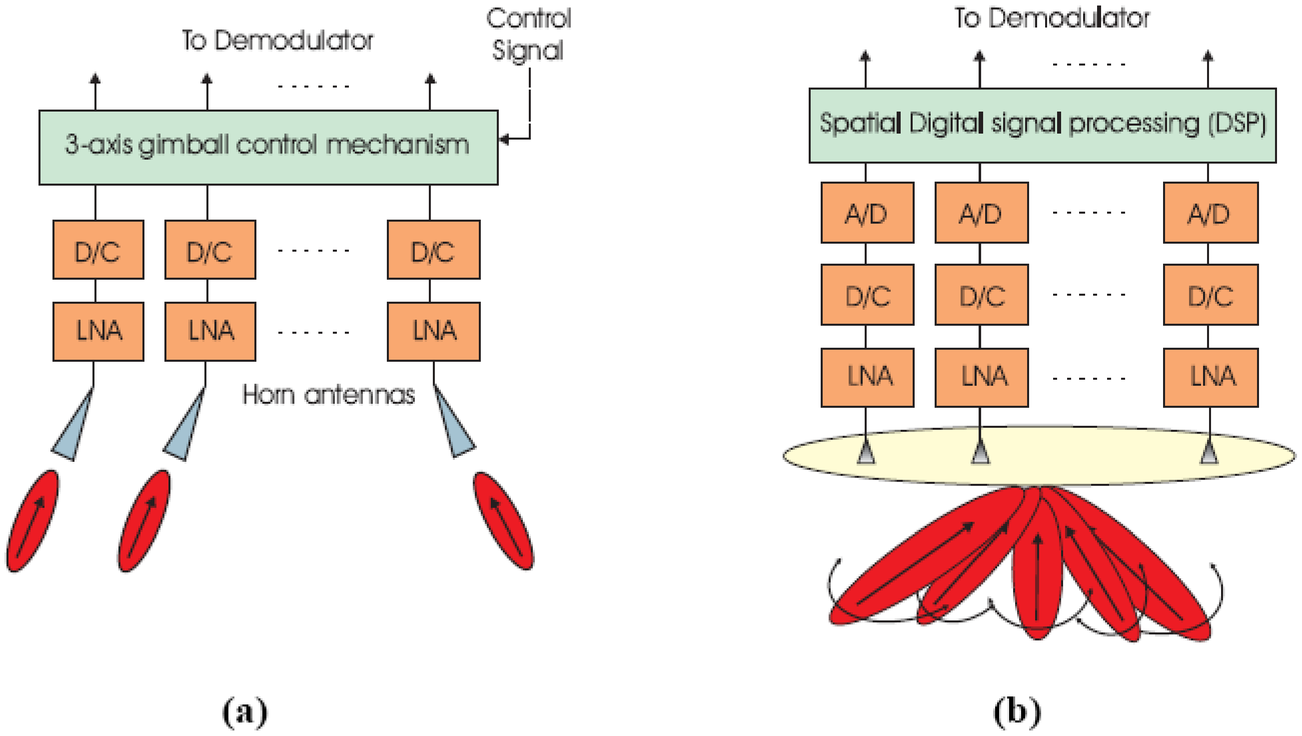


Fig. 36. Basic configuration of prototype multibeam antennas (in case of receiving)

(a) Multibeam Horn (MBH) antenna

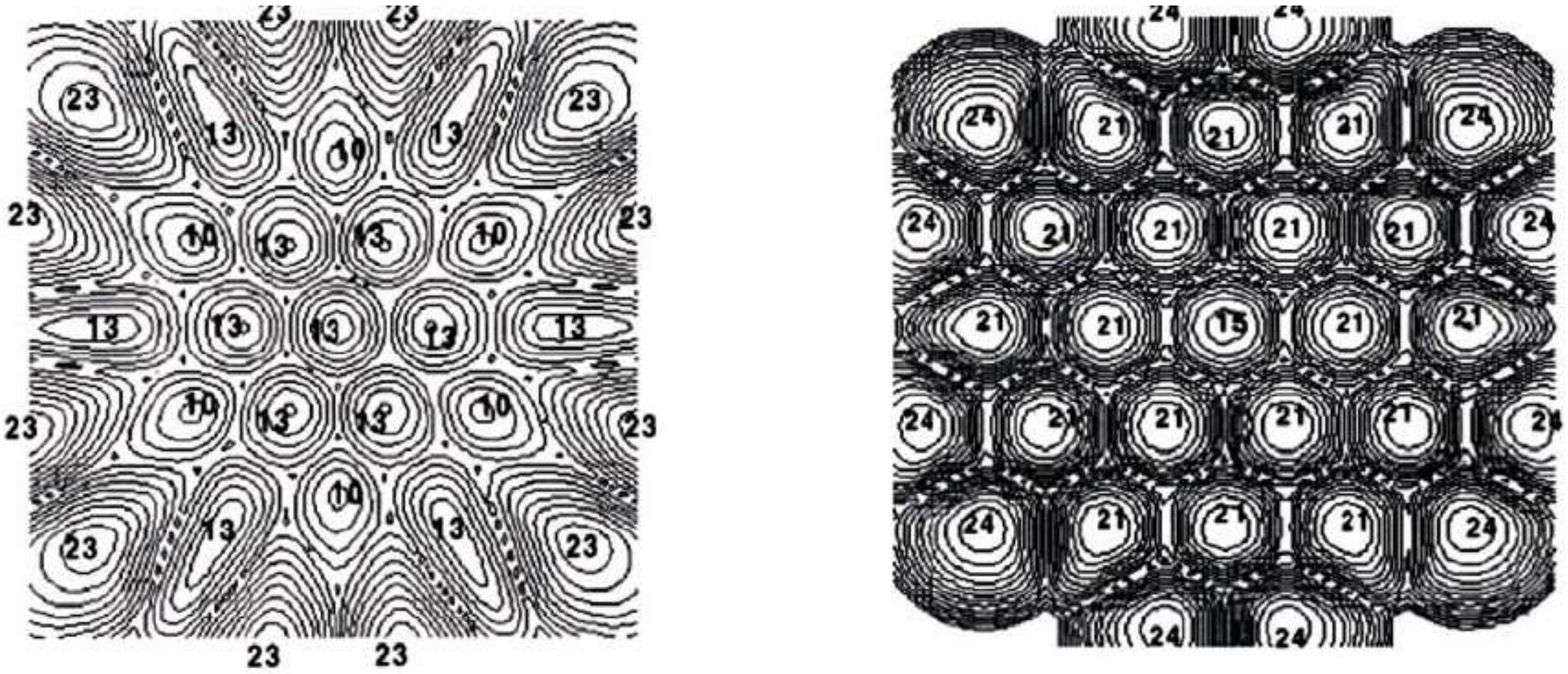
(b) Digital Beamforming (DBF) antenna

(this is a redrawn version of the figure that appeared in [3])

Table XII. Main specifications of the multibeam antenna prototypes *(this table appeared in [3])*

Item	MBH antenna	DBF antenna
Frequency band	T_x 47.2-47.5 GHz R_x 47.9-48.2 GHz	T_x 27.5-28.35 GHz R_x 31.0-31.3 GHz
Antenna type	7 corrugated horns	16 (4x4) patch array
Spot beamwidth	12 °	10° ~ 13°
Number of beams	7 fixed beams	9 fixed beams and 3 tracking beams
Bandwidth	300 MHz or more	4 MHz
EIRP	6.3 dBW or more	11 ~ 15 dBW
G/T	-15.4 dB/K or more	-13 ~ -17 dB/K
Compensation for platform fluctuation	Position sensor and 3-axis gimbal control mechanism	Adaptive beamforming with spatial digital signal processing
Transmission bit rate	56 Mbps	4 Mbps
Power consumption	1.0 kW or less	1.6 kW or less
Weight	150 kg or less	74.2 kg
Others	Frequency reuse factor: 7 or less Isolation between co-channel beams: 30 dB or more	Sampling rate: 32 MHz Resolution: 12 bits DSP device: FPGA (R_x: 100 k gates x 61, T_x: 100 k gates x 31)

Fig. 37. Prototypes of multibeam antennas, (a) MBH antenna (R_x) (7 elements, 47/48 GHz Band), (b) DBF antenna (R_x) (16 elements, 28/31 GHz Band) *(this photo appeared in [7])*



(a) (b)

Fig. 38. CIR contours for one channel of four. (a) circular beams, (b) Optimized elliptic beams *(this figure appeared in [38])*

High Throughput Satellites

- Definition
  - Multi-spot beam, multiple frequency re-use
  - Significantly greater throughput from a given orbital location compared to traditional FSS designs
  - HTS satellites are not restricted to Ka band
    - Some of the first HTS satellites operated at Ku band (IPStar)
    - Intelsat EPIC
  - GEO HTS
    - Regional
    - Global Constellations
  - MEO HTS Constellations
  - LEO HTS Constellations

GEO HTS Throughput Growth

Satellite	Year	Band	Throughput
Various		Ku/C	2 GHz
IPStar	2005	Ku/Ka	45 Gbps
Wildblue-1	2006	Ka	8 Gbps
Spaceway-3	2007	Ka	10 Gbps
Ka-Sat	2010	Ka	90 Gbps
ViaSat-1	2012	Ka	140 Gbps
NBN-1a	2015	Ka	135 Gbps
Viasat-2	2016	Ka	>200 Gbps
Viasat-3	2019 (planned)	Ka	1 Tbps

Closed versus Open Systems

- Closed Systems
  - Purchase managed service (Mbps)
  - Pre-defined standardised service offering
  - Asymmetric services are typical
  - Remote terminals standardised
  - All traffic must flow through operator’s gateways
  - QoS is pre-defined
- Open Systems
  - Can purchase MHz
    - Hybrid models also offer managed service options
  - Offerings are tailored for specific applications
  - Third party gateways are possible
  - QoS is determined by network configuration

Existing HTS Systems

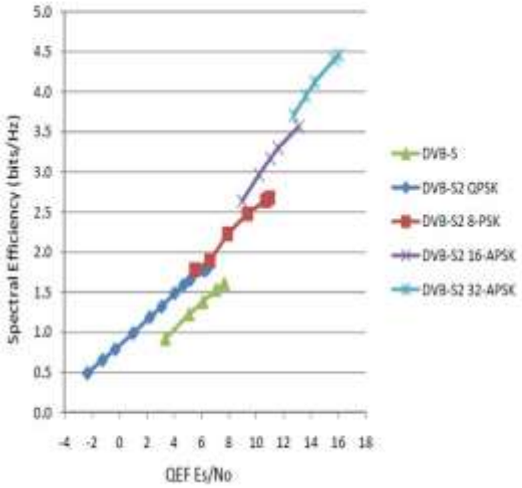
- Closed Systems
  - Fully Integrated Offerings
    - ViaSat
    - Hughesnet
  - Satellite Operator / Vendor Partnership
    - Inmarsat GX iDirect
    - Eutelsat tooway ViaSat
    - Yahsat Hughes
    - Telesat Vantage 19 Hughes
    - NBNCo ViaSat
- Open Systems
    - Intelsat Epic
    - IPStar
    - Inmarsat High Capacity Overlay Payload
    - O3b (MEO constellation)

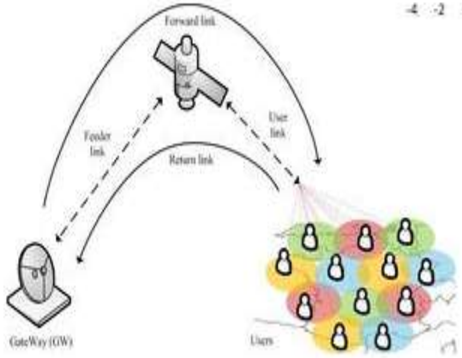
Is HTS a Disruptive Technology?

- Changing the metrics of the satellite industry
  - Mbps versus MHz
  - Fill-rate – what is the valid measurement?
  - End-to-end solutions
  - Packaged solutions rather than bespoke solutions
- Potential to cannibalise existing FSS revenues
  - ViaSat-3 constellation = 2 x total capacity of existing GEO fleet
- Impact on service providers and teleport operators
  - Defined gateway locations
  - Operator build out of unified network
  - Limited opportunities for third party teleport operators

HTS System Design

- Total System Throughput is determined by:
  - Modulation Efficiency
  - Available Bandwidth
  - Frequency Re-use





HTS System Design

- Improving Total System Throughput:
  - Modulation Efficiency
    - Gains are limited by channel non-linearity
  - Available Bandwidth
    - Reduce colour count – wider transponder BW
    - Expansion into non-standard bands, new frequency bands
  - Frequency Re-use
    - Narrower beams, increased spotbeam count, increased frequency re-use

Future HTS Developments

- Demand drivers
  - quest for more throughput....the Netflix effect.....
- Fast, cheap, good
  - Pick any two.....

Future HTS Developments – Efficiency Drivers / Goals

- Increase Overall Throughput
  - Modulation efficiency
  - Use of new frequency bands for feeder links
    - Need to consider spectrum licensing and availability
- Reduce Cost per Bit
  - Space segment cost – improve efficiency
  - Gateway efficiency – throughput / number of gateways
  - Reduce cost of user equipment / antennas / installation
- Flexible Architecture
  - Respond to changing market demands
  - Increased deployment of processing payloads

Future HTS Developments – Additional Spectrum

- Use additional feeder link spectrum
  - Q band
    - Space-to-earth 37.5 – 42.5 GHz
  - V band
    - Earth-to-space 47.2-51.4 GHz
  - W band
    - Space-to-earth 71-76 GHz
    - Earth-to-space 81-86 GHz
- Most ITU filings already include Q and V band
  - The race for spectrum has begun early
- Equipment availability limited at this time

Non-GEO Constellations

- Optical Constellation
  - Laser Light
  - MEO constellation, 8 satellites, 6 Tbps throughput
- Recent announcements of LEO HTS systems
  - COMMstellation 75 satellites
  - LEOSat 120-140
  - Oneweb 700
  - SpaceX 4000
  - Samsung 4600
  - Xinwei 30

HTS Constellations

- Deployment of LEO HTS networks will represent order of magnitude increase in HTS capacity
  - 2013 500 Gbps
  - 2023 2500 Gbps
  - 2023 with one LEO 8500 Gbps
  - 2023 with three LEO 25000 Gbps

Source: Northern Skies Research

Antenna : Satellite News Gathering

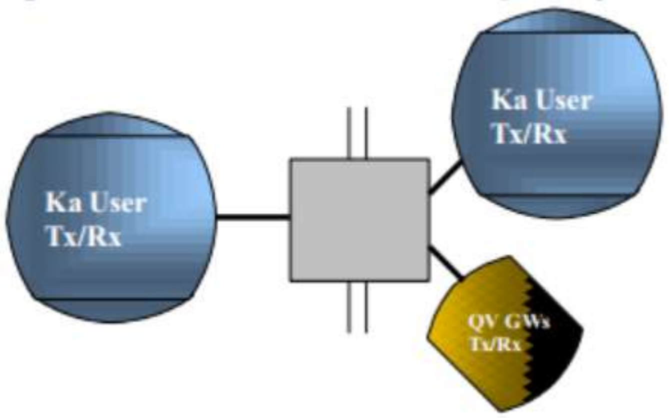
Telkom University

Antenna : Comms on the Move

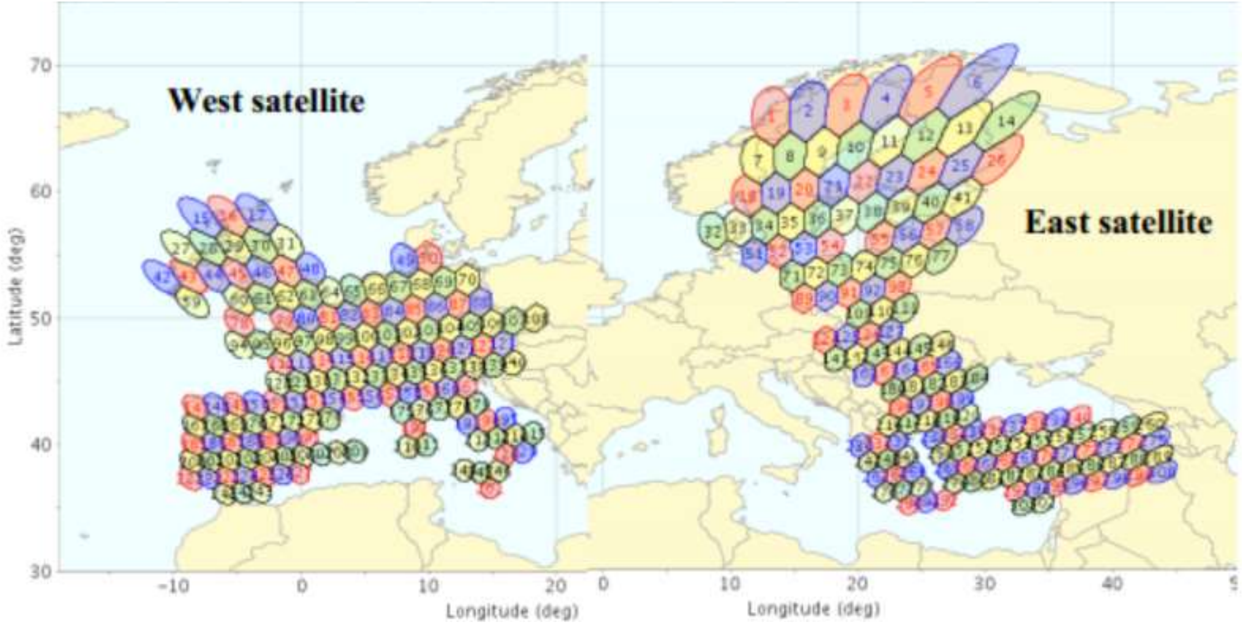
Maritime Antennas

Aeronautical antennas

BATS project : an example of HTS System over Europe (2020)



- Founded by Europe Commision
- 2012 – 2015
- 15 European Partners



- 300 user beams on EU28 + Turkey with 0.21o beamwidth
- Two satellites
- Each satellite involves 2 Ka-band antennas with 4.8 m reflectors and a Q/V-band antenna with 2 m reflector

BATS project : an example of HTS System over Europe (2020)

- System performance :
  - Throughput (with 2 satellites)
    - Forward link 750 Gbps
    - Return link 250 Gbps
  - Payload supported by evolved NEOSAT satellite platform
    - Mass : 1600 Kg (payload only)
    - Power : 18 KW
  - 25 Gateways per satellite → 50 gateways in the system + redundant sites for diversity

BATS : Broadband Access via integrated Terrestrial and Satellite Systems