High altitude Platforms for Wireless Communications (HAPs)

S-72.4210 Postgraduate Seminar on Wideband Radio Communications

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MOTIVATIONS

- HAPS COMBINES BEST FEATURES OF SATELLITE AND FIXED WIRELESS ACCESS (FWA) SERVICES.

- A QUITE SHORT ROUND TRIP DELAY

- A QUITE SMALL PROPAGATION LOSS

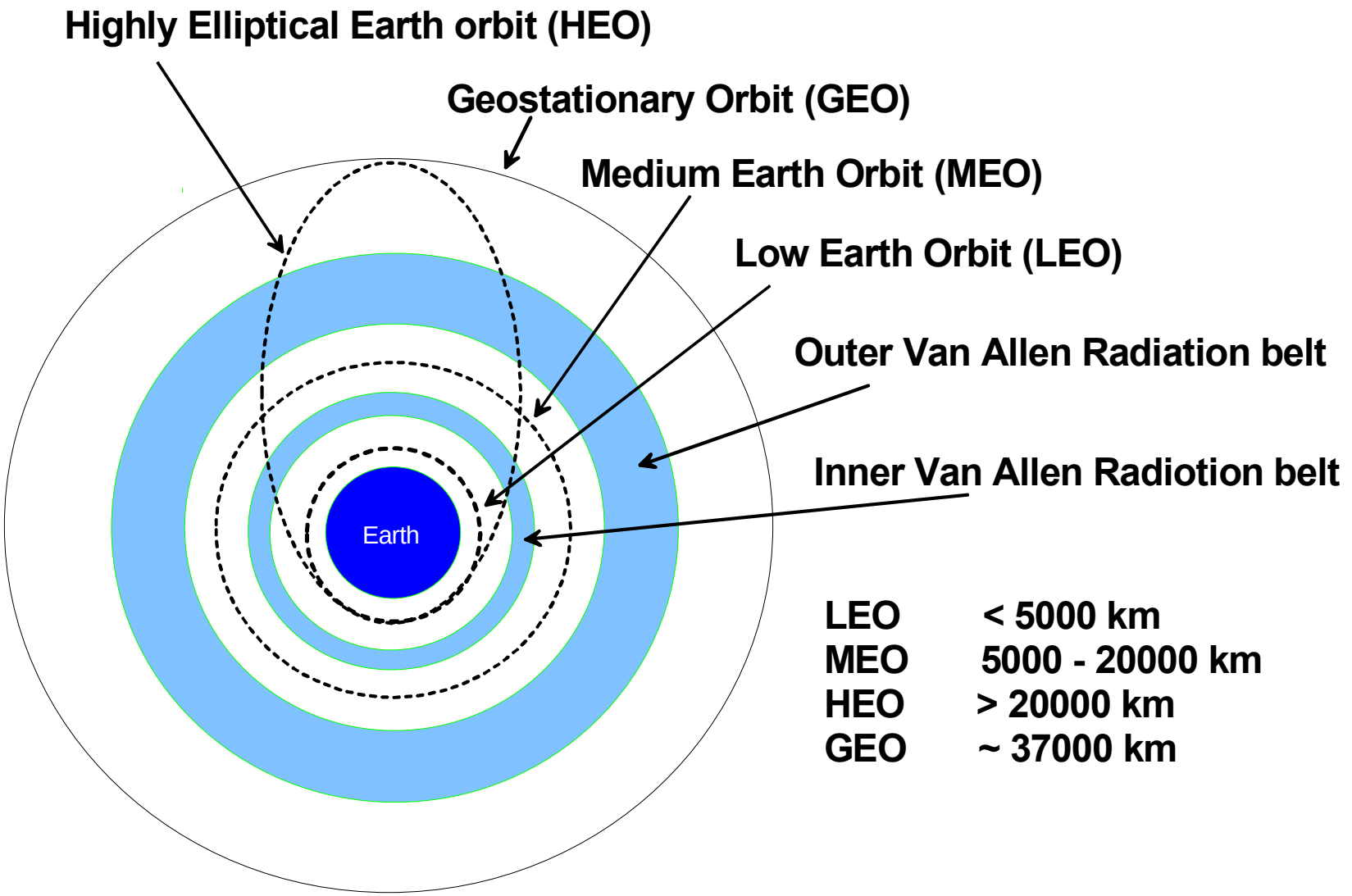
- ONE HAPS CAN COVER QUITE LARGE AREAS

- ENVIRONMENTALLY FRIENTLY SOLUTIONS

- RE-USE

- LARGE CAPACITY

SATELLITE ORBITS 1/2



SATELLITE ORBITS 2/2

1. LEO (LOW EARTH ORBIT) < 5000 KM
- **THE PERIOD OF THIS TYPE SATELLITE IS ABOUT 2 – 4 HOURS.**

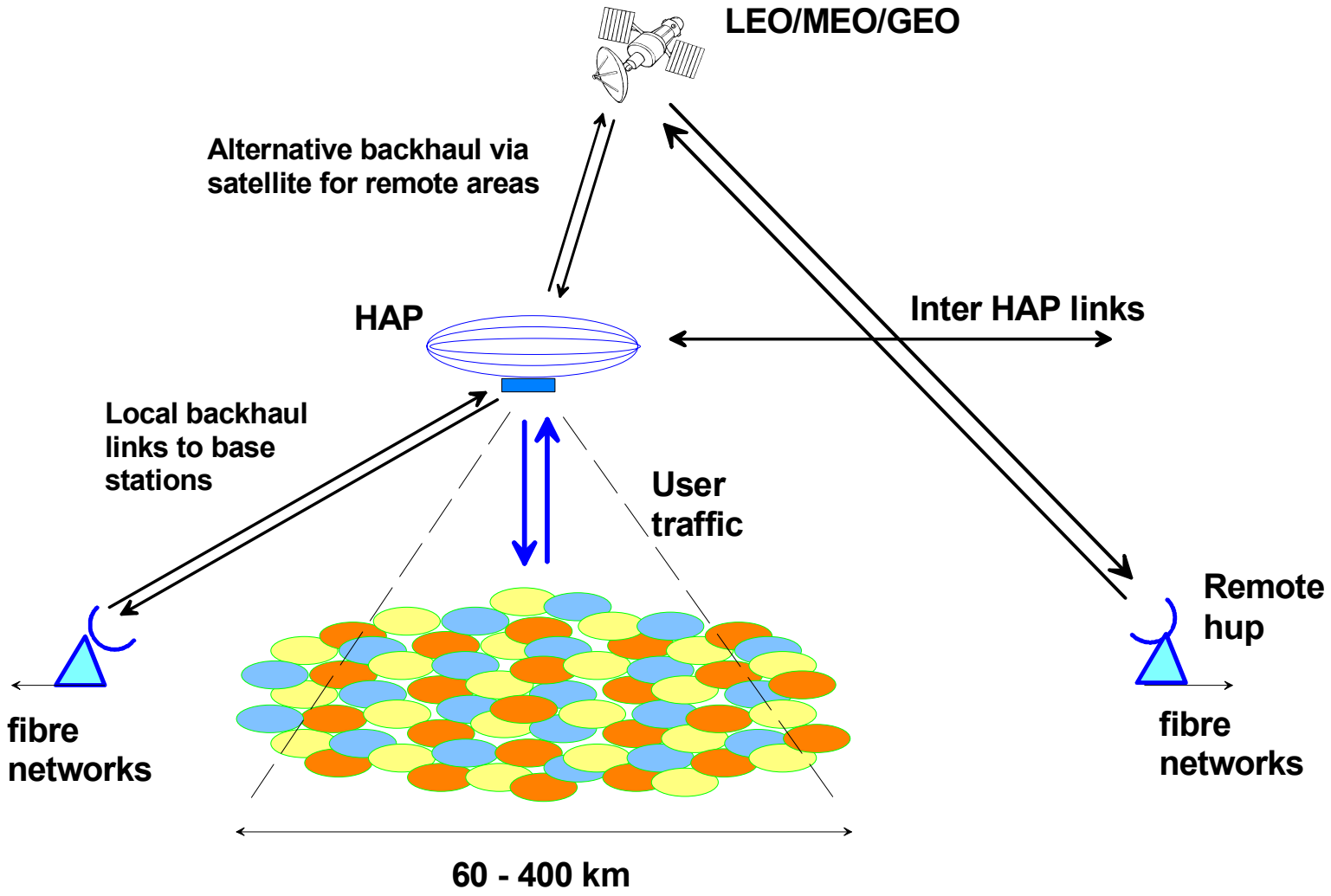
2. MEO (MEDIA EARTH ORBIT) 5000 – 20000 KM
- **THE PERIOD OF THIS TYPE SATELLITE IS ABOUT 4 – 12 HOURS.**

3. HEO (HIGHLY ELLIPTICAL ORBIT) > 20000 KM
- **THE PERIOD OF THIS TYPE SATELLITE IS MORE THAN 12 HOURS.**

THE VAN ALLEN RADIATION BELTS
WHERE ENERGETIC PARTICLES SUCH AS PROTONS AND ELECTRONS ARE CONFINED BY THE EARTH`S MAGNETIC FIELD.
THEY CAN DAMAGE THE ELECTRONIC AND ELECTRICAL COMPONENTS OF THE SATELLITE

SPACE DEBRIS BELTS
WHERE SPACECRAFTS ARE ABANDONED AT END OF THEIR LIFETIME. SPACECRAFTS ARE BECOMING AN INCREASING PROBLEM TO THE INTERNATIONAL COMMUNITY AS THEY CAN ALSO CAUSE DAMAGE TO SATELLITE NETWORKS AND TO SPACE MISSIONS IN THE FUTURE

HIGH ALTITUDE PLATFORMS



HIGH ALTITUDE PLATFORMS, TECHNOLOGY

AIRSHIP HAPS

- VERY LARGE SEMI RIGID OR NON RIGID HELIUMFILLED CONTAINERS
- LENGTH IS 100M OR MORE
- ELECTRIC MOTORS AND ROPELLERS ARE USED FOR STATION KEEPING
- PRIME POWER IS USED FOR PROPULSION AND STATION KEEPING AND ALSO PAYLOAD AND APPLICATIONS
- SOLAR CELLS MAY WEIGH TYPICALLY BELLOW 400g/m^2
- DURING THE DAY, POWER FROM THE SOLAR CELLS IS STORED IN REGENERATIVE FUEL CELLS SO THAT THE POWER CAN BE USED AT NIGTH
- THE ACHHIEVABLE MISSION DURATION IS HOPED TO BE ABOUT 5 YEARS

AEROPLANE HAPS

- UNMANNED SOLAR-POWERED PLANE
- IT IS FLYING AGAINST THE WIND OR CIRCULAR PATH
- ENERGY IS A QUESTION
- HELIOS PLANE (AERO VIRONMENT)
- ALREADY DEMONSTRATED (TO 25 KM ALTITUDE)

UAV, UNMANNED AERIAL VEHICLE

- IT IS TYPICALLY UNMANNED AIRCRAFT, ONLY FOR A SHORT TIME MISSIONS
- OPERATES NORMALLY AT A QUITE LOW ALTITUDE
- MAINLY USED IN MILITARY PURPOSES

A TETHERED AEROSTAT

- THIS IS AN AIRSHIP ON A CABLE. LENGHT MAY REACH UP TO 5 KM

HIGH ALTITUDE PLATFORMS, PROJECTS 1/3

HAPCOS:

COST297 – HIGH ALTITUDE PLATFORMS FOR COMMINUCATIONS AND OTHER SERVICES

- **HAPCOS IS A NEW EUROPEAN COST ACTION WHICH MAIN OBJECTIVE IS:**
- **TO INCREASE KNOWLEDGE AND UNDERSTANDING OF THE USE OF HIGH ALTITUDE PLATFORMS (HAPS) FOR DELIVERY OF COMMUNICATIONS AND OTHER SERVICES, BY EXPLORING , RESEARCHING AND DEVELOPING NEW METHODS, ANALYSES, TECHNIQUES AND STRATEGIES FOR DEVELOPERS, SERVICE PROVIDERS, SYSTEM INTEGRATORS AND REGULATORS.**

- **NEXT MEETING OF COTS297 WILL TAKE PLACE ON APRIL, 5TH TO 7TH, 2006**

THE CAPINA PROJECT:

- **MULTIPARTNER PROJECT. IT STARTED NOVEMBER OF 2003, 3 YEAR PROJECT.**
- **IT FOLLOWS HELINET PROJECT**
- **PRIMARY AIM IS PROVIDE TECHNOLOGY THAT WILL DELIVER DATA RATE UP TO 120 MBIT/S TO THE USERS IN THE RURAL AREAS.**
- **FOUNDED BY EU**
- **COORDINATED BY YORK ELECTRONICS CENTRE**
- **THERE ARE CONNECTIONS ALSO TO THE JAPAN HAP PROJECTS AND ALSO TO NASA**

HIGH ALTITUDE PLATFORMS, PROJECTS 2/3

THE HELINET PROJECT:

- A NETWORK OF STATOSPHERIC PLATFORMS FOR TRAFFIC MONITORING, SURVEILLANCE AND BROADBAND SERVICES
- THIS PROJECT RAN BETWEEN JANUARY 2000 – MAY 2003 AND WAS FUNDED BY UNION FRAMEWORK 5 PROGRAMME (EU)
- MEMBERS: UK, HUNGARY, SPAIN, ITALY, SWITZERLAND, SLOVENIA

THE PROJECT FOCUSSED ON AREAS UNDER:
• DESIGN OF A SCALED SIZE PROTOTYPE OF SOLAR POWERED PLANE (HAP)
• DEVELOPMENT OF TREE MAJOR APLLICATIONS
- TRAFFIC MONITORING
- ENVIRONMENTAL SURVEILLANCE
- BROADBAND TELECOMMUNICATIONS

USED FREQUENCY WAS 48 MHZ

RESEARCH AREAS:
- SYSTEM LEVEL DESIGN
- PROPAGATION AND DIVERSITY
- MODULATION AND CODING TECHNIQUES
- RESOURCE ALLOCATION AND NETWORK PROTOCOLS
- RF ANTENNA HARDWARE DESIGN AND DEVELOPMENT AT 48 GHZ

HIGH ALTITUDE PLATFORMS, PROJECTS 3/3

SKYNET (JAPAN):
- TO PRODUCE AN INTEGRATED NETWORK ABOUT 15 AIRSHIPS
- USES 25 GHZ BAND

HALO PROJECT:
- USES A MANNED AIRCRAFT WITH PILOTS OPERATING ON AN 8 HOUR SHIFT
- IT IS CURRENTLY QUITE NEAR TO COME TO MARKET ?
- OPERATING ALTITUDE IS 16 – 18 KM
- FLIES IN A CIRCULAR PATH AT THE ALTITUDE OF ABOUT 13 KM
- USES UP TO 125 MICROWAVE ANTENNAS

PLATFORMS WIRELESS INTERNATIONAL
- USES TETHERED AEROSTAT FOR COMMUNICATION PURPOSES IN BRAZIL
- ALTITUDE 4 – 6 KM
- CELLULAR COMMUNICATION SERVICES TO OVER 125000 SUBSCRIBERS

ADVANTAGES OF HAPS, COMPARED WITH THE TERRESTRIAL SERVICES

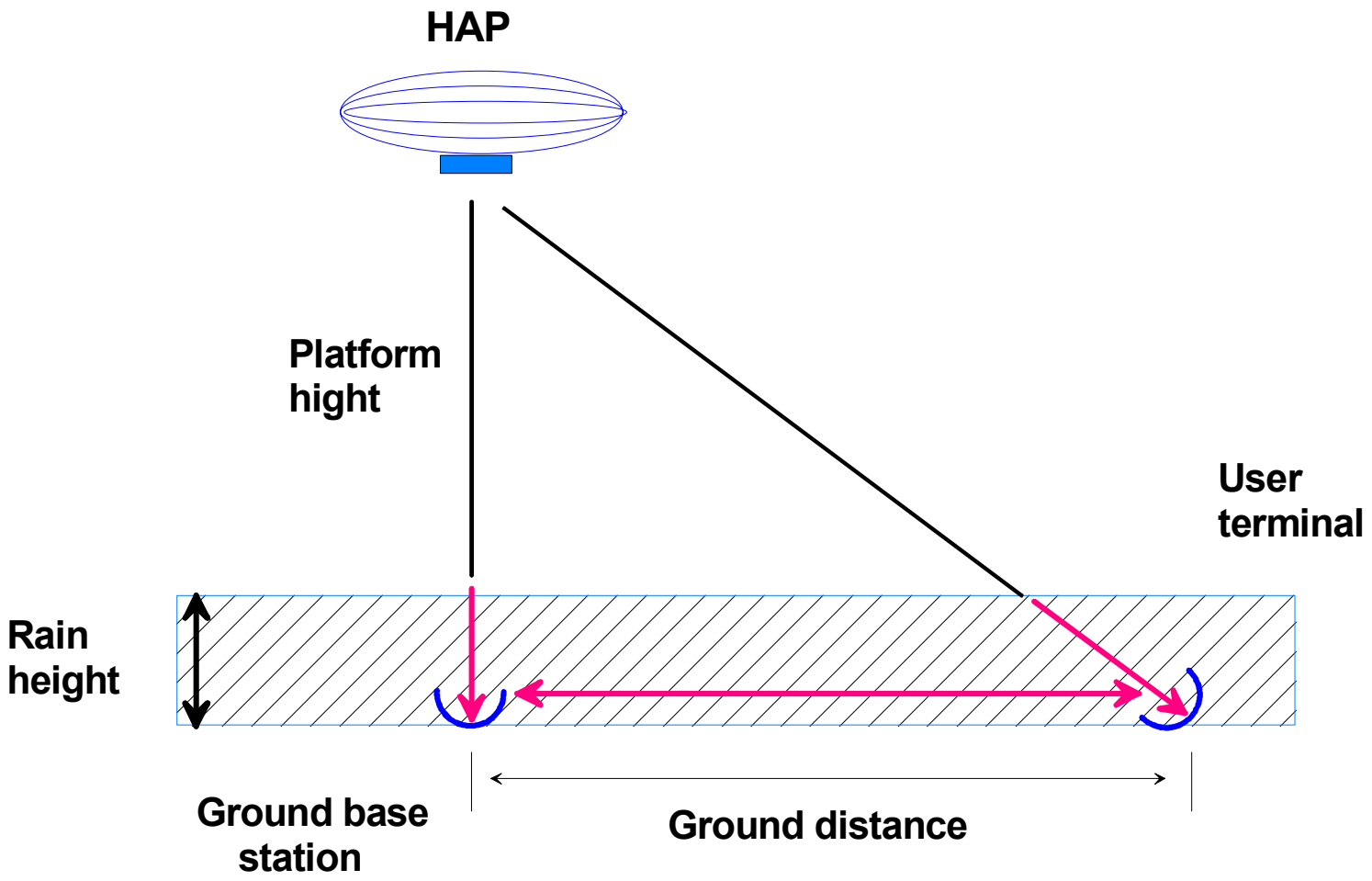
REPLACE EXTENSIVE GROUND BASED INFRASTRUCTURE
- 1 HAP CAN PROVIDE MULTI CELLULAR SERVICES OVER LARGE AREAS
- WE DO NOT NEED A LOCAL TERRESTRIAL BACKBONE
- BACKHAUL CAN BE PROVIDED TO A PLACE WHERE FIBRE OPTICS ARE AVAILABLE

BETTER PROPACATION IN MANY SCENARIOS (ALTITUDE ~22 KM)
- LINE OF SIGHT PATHS
- RAIN MAY AFFECT THE HAP SYSTEMS LESS THAN TERRESTRIAL SYSTEMS

LARGE SYSTEM CAPACITY
- USE OF MM BANDS (47/48 GHZ, 2X300 MHZ BANDS)
- FREQUENCY RE-USE
- FLEXIBLE AND ADAPTIVE RESOURCE ALLOCATION

RAPID DEPLOYMENT

HIGH ALTITUDE PLATFORMS, RAIN



ADVANTAGES OF HAPS, COMPARED WITH THE SATELLITE SERVICES

LARGE OVERALL SYSTEM CAPACITY
- SMALL SPOT BEAMS (CELLS) READILY FEASIBLY WITHOUT HUGE ANTENNAS ON BOARD

⇒ MUCH BETTER THAN GEO OR LEO SATELLITES

SHORTER PATHS => LINK BUDGETS BETTER
- TYPICALLY ~ 34 DB BETTER BUDGES THAN LEO AND ~ 66 DB BETTER THAN GEO

LOW ALTITUDE => SHORT PATHS` LENGTH => LOW DELAY
- NO PROBLEMS WITH PROTOCOLS? (TCP/IP)

LOWER COST
- NO LAUNCH VEHICLE
- LESS DEMANTING THAN SPACE SYSTEMS

RAPID DEPLOIMENT
- NO LONG LEAD TIME
- EASY UPGRATE AND MAINTENANCE

INCREMENTAL DEPLOYMENT
- NEEDS ONLY ONE HAP TO START

ENVIRONMENTALLY FRIENTLY
- NO LAUNCH VEHICLE/ROCKET
- SOLAR POWER

FREE SPACE PROPAGATION

FREE SPACE PROPAGATION LOSS:

THIS IS THE LOSS THAT CAN OCCUR BETWEEN THE ANTENNAS IF THE ANTENNAS ARE ISOTROPIC ANTENNAS LOCATED IN A PERFECT DIELECTRIC, HOMOGENEOUS, ISOTROPIC AND UNLIMITED ENVIRONMENT.

IT IS GIVEN, IN DESIBELS

$$L(dB) = 20 \log (4\pi d / \lambda)$$

WHERE
d = THE PATH LENGTH
λ = WAVE LENGTH

THERE IS ALSO MORE COMMONLY USED FORM:

$$L(dB) = 32.4 + 20 \log (f_{MHz}\, d_{km})$$

THE PROPAGATION DELAY FROM EARTH STATION TO THE SATELLITE CAN BE CALCULATE AS:

$T = R / C$, **WHERE VELOCITY OF LIGTH** $C = 3 \times 10^8$ **m/s**

HAPS, COMMUNICATIONS DESIGN ISSUES

NETWORK TOPOLOGY:

- HAPS CAN BE WORKED LIKE PROCESSING SYSTEM(OR SWITCHING) OR TRANSPARENT MODE.
- INTER HAP LINKS MAY BE ARE VERY FEASIBLE
- BACKHAUL LINKS MAY BE A BIG CHALLENCE

AIR INTERFACE AND PROTOCOLS:

- BASIS ARE IEEE 802.16, WHICH IS WIMAX STANDARDS
- A MODIFIED VERSION OF THAT IEEE STANDARDS ARE USED MAY BE REASON TO USE THAT IS:
• CAPACITY / USER
• CAPASITY / USED SECTOR
• MANAGEMENT OF USERS
• SECURITY QUESTIONS (DES AND AES ALGORITM ARE USED IN WIMAX)
• POINT-TO-MULTIPOINT USE

HAPS, SOME CHALLENGES

- SYSTEM LEVEL REQUIREMENTS (FREQUENCY PLANING, ARCHITECTURE…)
- PROPAGATION AND DIVERSITY (RAIN, SCATTERING…)
- MODULATION AND CODING (QoS, BER, FEC…)
- RESOURCE ALLOCATION AND NETWORK PROTOCOLS (BWA SERVICES)
- ANTENNAS (PHASED ARRAY…)
- HAP STATION KEEPING AND STABILITY
- HANDOFF OR HANDOVER (ROAMING)
- PAYLOAD POWER

USE OF HAPS IN THE FUTURE

- BROADBAND WIRELESS ACCESS (BWA)
- INTERNET
- BROADCAST (TV OR RADIO)
- 3G, UMTS, IMT -2000
- BANDWITH ON DEMAND
- OIL/GAS/MINERAL EXPLORATION
- SURVEILLANCE AND POSITIONING
- DIFFERENTIAL GBS
- REMOTE SENSING
- SEISMIC MONITORING
- FLOOD DETECTION
- TRAFFIC MONITORING AND CONTROL
- TACTICAL COMMUNICATIONS

HOMEWORK

1 a) Calculate a free space propagation loss from a base station to the HAPS and HAPS to the GEO satellite. We are using 48 GHz frequency.
You can use the given altitudes.

1 b) Calculate a round trip time.

2. Why we are desining the HAPS systems? What are the main reasons?

REFERENCES

[1] Simon Haykin, Michael Moher, Modern Wireless Communications, Prentice Hall, USA 2004.

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[3] Satellite Networking, Principles and Protocols, Zhili Sun, West Sussex, England 2005, Wiley.

[4] High Altitude Platforms for Wireless Communications, T.C.Tozer, D. Grace, Electronics&Communication Engineering Journal June 2001.