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High Altitude Platform – Future of Infrastructure

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***Abstract*—High Altitude Platform (HAP) concept and idea is presented in the article. Characteristics, advantages and disadvantages of HAPs are described. There is also the comparison available between HAPs and existing telecommunication infrastructure (terrestrial and satellite). Selected examples of the possible limitation and technological restrictions of HAP based systems are presented in the article.**

***Keywords*—HAP, High Altitude Platform, rural area, infrastructure.**

I. INTRODUCTION

CONSTANT growth of interest in high speed wireless communication causes the search for new solutions and new concepts of radio access networks. High Altitude Platforms (HAPs) are a very good example of this trend. New type of infrastructure can be easily deployed to support existing systems. HAP network combines advantages of both terrestrial and satellite radio access networks. Simultaneously, HAPs are devoid of many restrictions and disadvantages characteristic for existing infrastructure.

High Altitude Platform (HAP) can be a plane, airship or balloon located on the altitude between 17 and 22km and dedicated to providing telecommunication services. Altitude range has been chosen due to the following reasons:

• it is located beyond the planes' altitude,
• mean wind speed is relatively small (Fig. 1),
• relatively big coverage area with simultaneously low transmission delay.

Maximum HAP work time strictly depends on the solution. It can be from a few hours (e.g. manned plane) up to one and a half years (e.g. unmanned airship).

Frequency bands dedicated for HAPs have been assigned by ITU (International Telecommunication Union):

• 47,2 – 47,5GHz and 47,9 – 48,2GHz (fixed service),
• 27,5 – 28,35GHz and 31,0 – 31,3GHz (fixed service, region 3),
• 1885 – 1980MHz and 2110 – 2160MHz (IMT-2000/UMTS, region 2),
• 1885 – 1980MHz, 2010 – 2025MHz and 2110 – 2170MHz (IMT-2000/ UMTS, regions 1 and 3).

II. TYPES OF HIGH ALTITUDE PLATFORMS

Two types of HAPs can be distinguished: heavier than the air and lighter than the air.

According to anticipations, first commercial solutions will be based on those heavier than the air platforms. However, the target solutions will be lighter than the air airships.

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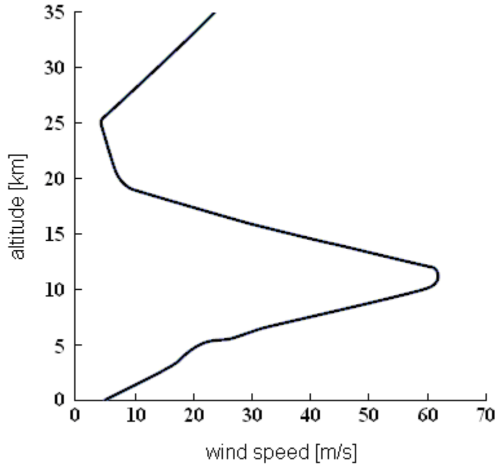

Fig. 1. Depicts the wind speed against the altitude [11].

A. Heavier than the Air

In this group, the most promising solutions are unmanned planes hydrogen powered (e.g. Global Observer [12]) or solar powered (e.g. Pathfinder Plus [18]). In order to keep a predefined position, the plane must fly against the wind or circulate on predefined route (usually in a circle). Advantages of this solution can be fast and easy platform deployment and movement from one service area to another. Disadvantages of this solution can be lack of capacity and electric power.

A second possible solution can be manned planes. However, in his case working time is limited to few hours. This solution is dedicated mainly to providing emergency connections for the areas afflicted with disaster. It can be also successfully used in case of short term growth of telecommunication traffic

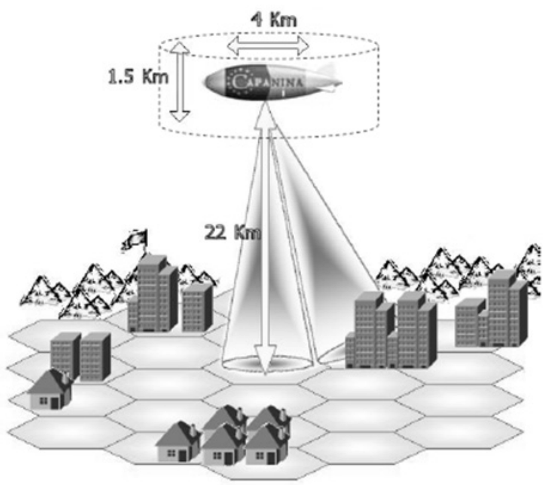

Fig. 2. HAP usage scenario developed by Capanina Project [4].

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on the coverage area (e.g. sport competitions, trades, local events). Besides short work time, manned planes have another disadvantage – jet engines generate a lot of atmospheric pollutions.

B. Lighter than the Air

Airships are considered as the most interesting and the most welcome solution. They are characterized by many advantages, but the most important are: long term work time (up to one and a half years) and large capacity. Equipped with electric motors used to hold the geostationary position, airships do not generate any pollution to the atmosphere. Lockheed Martin HAA [17] can be a very good example of the airship designed to work as a high altitude platform.

Also, balloons belong to the lighter than the air group. They cannot be treated as a target commercial solution because of their maximum work altitude which reaches only 5km. However, they can be used for scientific researches and measurements.

III. High Altitude Platforms vs. Terrestrial and Satellite Systems

Current terrestrial and satellite systems, despite many advantages, have also many disadvantages. In the first case the main disadvantages are: long term deployment, there are many reflections on the propagation way, and the signal is highly reduced by terrain obstacles (non LOS propagation). In case of geostationary satellites there are the following disadvantages: significant propagation delay and propagation loss. In case of the system based on the LEO satellites it is necessary to create the whole constellation to provide uninterrupted services.

In comparison with terrestrial systems, HAPs have the following advantages:

- relatively low cost of system build up or modernization,
- very short time to start up the system,
- possibility to differentiate cells diameter from one to a few hundred kilometers,
- LOS connections availability on the major part of the coverage area
- lower rain attenuation influence,
- significantly larger coverage area (compared to single BTS),
- possibility of dynamic radio resources allocation,
- environmentally friendly,
- lack of problems with transmitter construction.

In comparison with satellite systems, HAPs have the following advantages:

- lower propagation losses,
- low propagation delay (<1ms in one direction),
- relatively low cost of system build up or modernization,
- very short time to start up the system,
- possibility to differentiate cells diameter from one to a few hundred kilometers,
- larger system capacity,
- environmentally friendly.

In case of both terrestrial and satellite systems it is very difficult to provide high speed transmission on the large, low populated areas. In first case it is very expensive to build a network of transceiver stations. GSM cell with a diameter of 35km provides coverage to the area of about 970 square kilometers. In the second case the overall system capacity is limited.

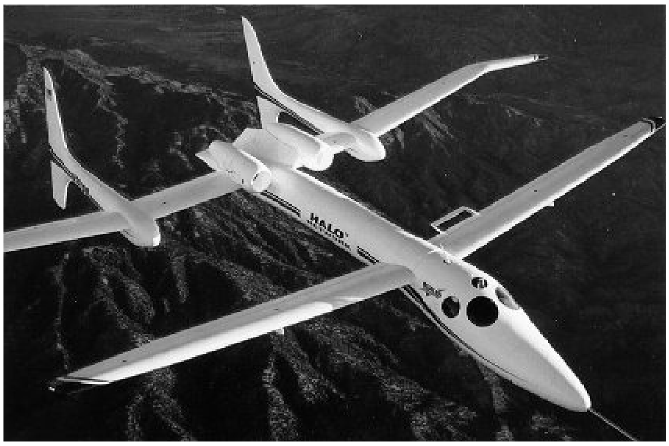

Fig. 3. Manned plane Proteus [1].

Fig. 4. Unmanned solar powered plane Helios [18].

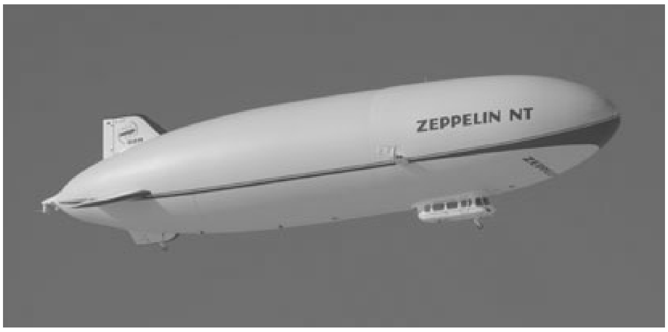

Fig. 5. Airship Zeppelin NT [19].

High Altitude Platforms are relatively cheap, easy to deploy and have significant capacity. System based on a single HAP can cover the area with a diameter of about 60km (HAP altitude 17km, minimum elevation angle 30 degrees) up to 420km (HAP altitude 22km, minimum elevation angle 5 degrees). It gives up to about 140 thousands square kilometers coverage area.

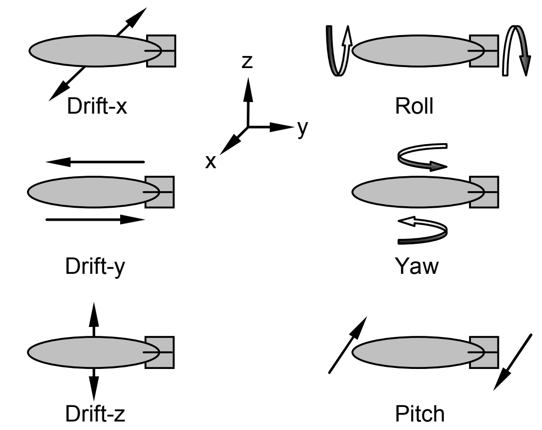

Fig. 6. Possible instabilities.

IV. Position Keeping, Platform Instability

During the HAP based system design process it is crucial to take into consideration instability of the platform (Fig. 6). Regarding to ITU recommendation HAP should be located in the area limited by the sphere with radius of 500m and the center of sphere should cover with the nominal HAP localization in space. However, it is impracticable in existing solutions. Therefore in most of the project it is assumed that HAP will be located in the space limited by a cylinder with radius of 2,5km and height of 1,5km (for 99% of time).

Instability can significantly influence the telecommunication system work through change of cell location, size and/or geometry (Fig. 7). There are solutions designed to compensate or even minimize platform instability.

One of the most simple and effective solution is a mechanical tracking which keeps HAP's antenna directed ground station. This technology is used e.g. on fast boats to provide constant connection with a satellite. Good example of this solution is Free-Space Experimental Laser Terminal for HAPs optical connections developed and tested by CAPANINA Project (Fig. 8).

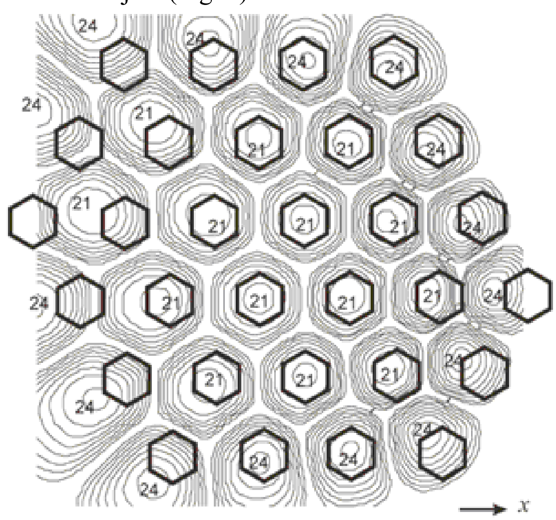

Fig. 7. HAP instability influence on cells location and geometry (2km displacement, central cell corrected) [10].

Fig. 8. Free-Space Experimental Laser Terminal (FELT) [3].

V. System Architecture

HAPs can be used as a part of a bigger system and work as a part of a radio access network only. They can coexist with both terrestrial and satellite radio access networks. However, HAPs can work as an independent system. In both cases it is possible to use one or many platforms which allow for expanding the service area.

A. *HAP as a Part of a Radio Access Network*

In the simplest case, high altitude platform is used only as a base transceiver station (Fig. 9). All connections between subscribers (even served by one platform) are put through in a switching center located on a surface.

B. *HAP as an Independent System*

In the case where high altitude platform works as an independent system, all necessary devices including the switching center are located on board (Fig. 10). Connection to the ground base station is used to establish the communication with other networks.

Connection with terrestrial network can be also put through the satellite link (Fig. 11). It is possible to establish the communication directly between two or more HAPs. Inter-Platform Links can use both optical and radio links [10]. Optical links can be also used as a backhaul link to ground base station [3]. It enables to reduce the use of available radio frequency bandwidths.

VI. Propagation Aspects

In the most promising scenarios 28/31GHz and 48GHz bands are used. Admittedly, in most cases there will be LOS propagation but it is very important to take into consideration atmospheric attenuation. Total attenuation due to multiple sources of simultaneously occurring atmospheric attenuation can be calculate from (1):

$$A_T(p) = A_G(p) + \sqrt{\left(A_R(p) + A_C(p)\right)^2 + A_S^2(p)} \qquad (1)$$

where:

p – fixed probability $\left(0{,}001\% \le p \le 50\%\right)$,

$A_G(p)$ – gaseous attenuation due to oxygen and water vapour for a fixed probability (dB),

$A_R(p)$ – rain attenuation for a fixed probability (dB),

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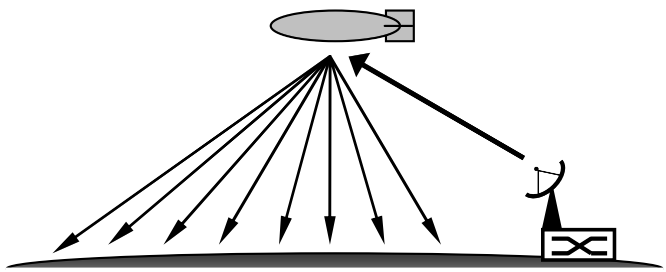

Fig. 9. HAP working as base transceiver station.

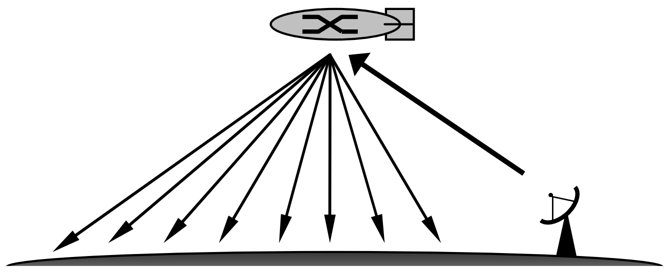

Fig. 10. HAP working as an independent system.

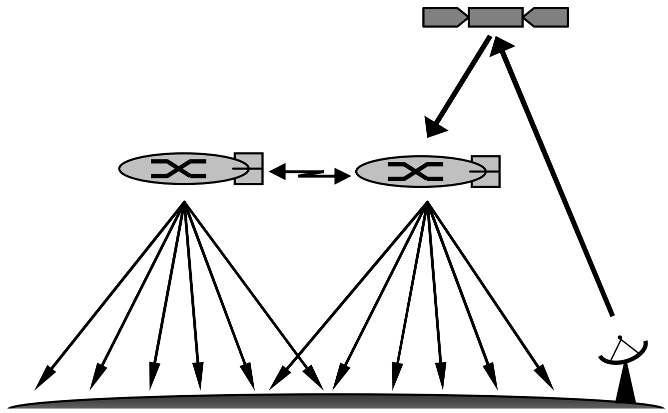

Fig. 11. Two HAPs connected with Inter-Platform Link and with the satellite backhaul link.

$A_C(p)$ – clouds attenuation for a fixed probability (dB),

$A_S(p)$ – attenuation due to tropospheric scintillation for a fixed probability (dB).

Considering as an example High Altitude Platform located at 21km using frequency band 48GHz. In this case total attenuation varies from 13,2dB (elevation angle 90 degrees) up to 141dB (elevation angle 5 degrees). In order to prevent system outage in case of e.g. heavy rain there are studies on different solution available. Quite simple and simultaneously promising solution is e.g. site diversity (Fig. 15) [15].

A. Atmospheric Gaseous Attenuation

Atmospheric gaseous attenuation is another important factor to be considered [2]. For the 48GHz band specific attenuation is 0,36dB/km. Depending on distance attenuation can be from 7,6dB (for 21km – elevation angle 90 degrees) up to 73,5dB (for 203km distance – elevation angle 5 degrees).

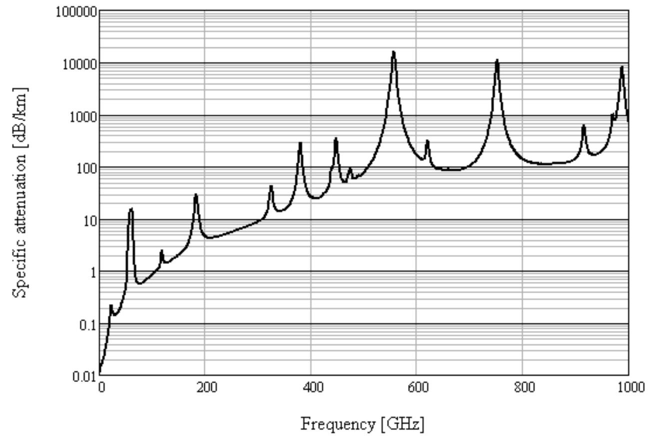

Fig. 12. Specific attenuation due to atmospheric gases [8].

B. Clouds Attenuation

Clouds attenuation can be calculated according to ITU Recommendation ITU-R P.840. The attenuation value grows with elevation angle reduction. In mentioned above scenario clouds attenuation will vary from 1dB (for 90 degrees elevation angle) up to 12,3dB (for 5 degrees elevation angle).

C. Rain Attenuation

Rain attenuation can be calculated according to ITU Recommendation ITU-R P.618. The attenuation value grows with elevation angle reduction. In mentioned above scenario clouds attenuation will vary from 4,53dB (for 90 degrees elevation angle) up to 55,33dB (for 5 degrees elevation angle). In rain attenuation calculations it is very important to consider proper polarization. Especially in case of small values of elevation angle results can significantly differ. In our example difference can be up to 5,8dB (horizontal polarization: 55,3dB; vertical polarization 49,5dB; circular polarization: 52,4dB).

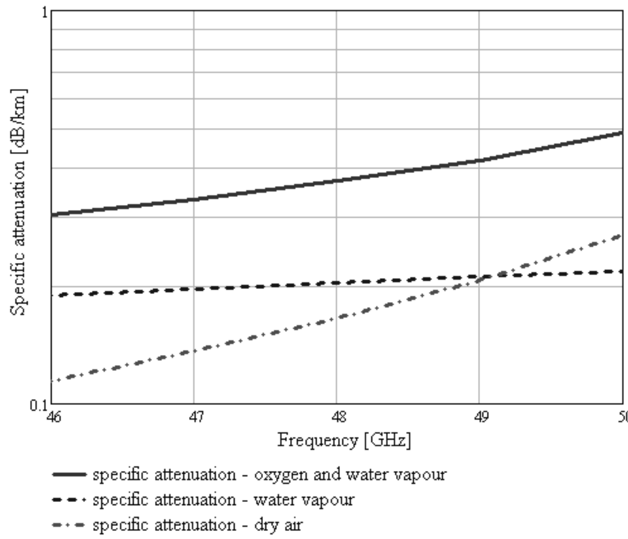

Fig. 13. Specific attenuation due to atmospheric gases (frequency band 46GHz – 50GHz).

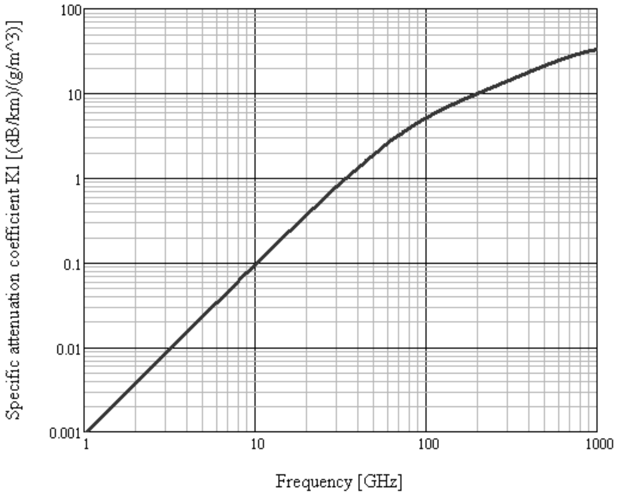

Fig. 14. Specific attenuation coefficient K_l used in clouds attenuation calculations.

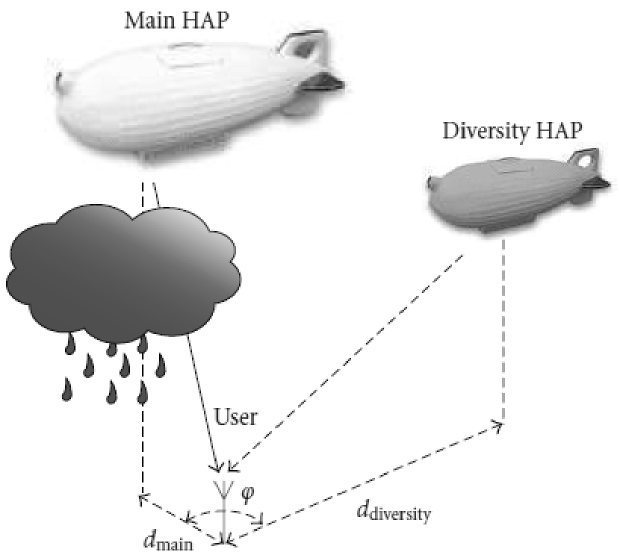

Fig. 15. Basic scenario for HAP diversity to prevent system outage [15].

D. *Tropospheric Scintillations*

Tropospheric scintillations' impact grows with elevation angle reduction. In considered scenario it can vary from about 0,2dB for 90 degrees elevation angle up to 3,5dB (for 5 degrees elevation angle).

VII. High Altitude Platform Usage for Rural Areas

A. *Coverage Area*

System based on High Altitude Platforms can be an optimal solution to provide broadband services to rural areas. A very large area can be easily covered by a single HAP (Fig. 16).

Taking into consideration that the platform is located at the altitude of 21km and the maximum elevation angle is 5 degrees it is possible to cover the area with 200km radius. With 30 degrees elevation angle the area is still quite large – 36km radius.

B. *System Capacity*

Apart from very optimistic approaches it can be difficult to provide high speed services to every subscriber simultaneously. There are two main constraints and limitations: available radio spectrum and power source on HAP. The first one brings the limit to the amount of data transmitted via a single backhaul link. The second one limits the amount of data transmitted from High Altitude Platform to subscribers.

If 200Mbit/s backhaul link is considered single HAP system, it can serve up to 400 simultaneous connections (0.5Mbit/s each). However, subscribers usually do not transmit with constant usage of full available bandwidth. With the assumption that only 2% of time is used for the transmission, 20000 subscribers can be served by a single platform.

VIII. Services

47/48GHz frequency bands available for HAPs allow creating of broadband networks. It is possible to use e.g. WiMax or DVB with return channel (DVB RCT, DVB RCS) techniques.

ITU also allows usage of IMT-2000/UMTS communication via HAP. 3G services provided via high altitude platform will be equivalent to those currently available in terrestrial networks. High altitude platforms can be used to extend UMTS network coverage to rural areas. They can also be used to establish an independent 3G network.

HAPs and intelligent antennas usage allows making the most of available radio resources. Dynamic change of cell sizes and the frequencies allocation per cell allows to reallocate radio resources to react on changing traffic conditions (e.g. during the day – city center, afternoon and weekend – suburbs and rural areas). It is also possible to create one huge cell with diameter up to 400km for fast moving subscribers (e.g. in fast trains, on motorways). It prevents handover and allows the reduction of signalization traffic.

High altitude platforms can be successfully used as a transmitter of digital radio and television. In particular, to cover the same area from HAP significant less transmit power is required than from terrestrial transceiver station. Researches conducted in SkyTower project shows that for high definition

Fig. 16. Coverage area radius in elevation angle function (HAP at 21km altitude).

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TABLE I
RESEARCH AND DEVELOPMENT PROJECTS FOUNDED BY EUROPEAN UNION

Frame Program	Project name	Starting year	Ending year
5	HeliNet	1999	2003
	CAPECON	2002	2005
6	CAPANINA	2003	2006
	HAAS	2002	2006

digital TV purpose, HAP transceiver with 1W output power is equivalent to terrestrial transceiver with 1kW output power [14].

Very importantly, HAP application can be emergency services for the areas afflicted with disaster (floods, hurricanes, earthquakes etc.). If the existing infrastructure has been damaged it is possible to set up a temporary emergency infrastructure using HAPs in a relatively short time.

It is also possible to use HAPs for services not based on data transmission. To this group we can assign localization services [12] and navigation services. They can be served with data transmission services simultaneously which allows to expand the network operator offer. Besides that, it is possible to use HAP as a transmitter of differential correction GPS signal, which leads to the increase of the precision of localization.

Clearly, it is only a summary of the most promising possible applications. Apart from that, there are many military services which are not described in this article. US Army already uses Predator UAV – HAPs usage seems to be the next step.

IX. European Union Projects

Research and development activities related to High Altitude Platforms are conducted all around the world. There were also significant research projects founded by European Union (Table 1).

A. HeliNet and CAPANINA

Started in December 1999, HeliNet project was coordinated by Politecnico di Torino. Research works were focused on HAVE (High Altitude Very long Endurance) platforms.

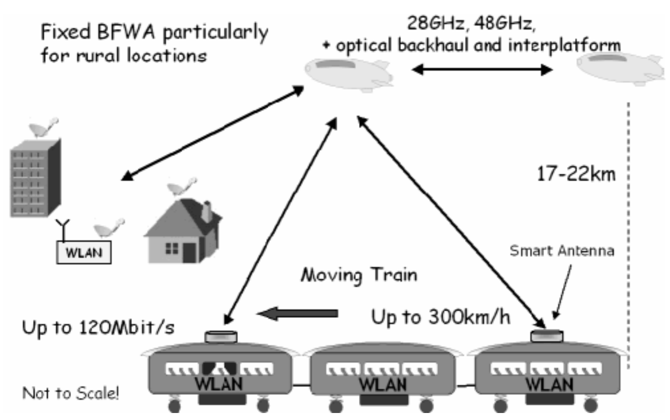

Fig. 17. Vision of HAP based system – CAPANINA Project [15].

CAPANINA project started in December 2003 as a successor of HeliNet. The goal was to analyze the possibilities to provide broadband services in rural areas and to the subscribers moving with speed up to 300km/h [16].

X. Conclusion

High altitude platforms can be a very good solution for rural areas. They combine advantages of both terrestrial and satellites systems, and simultaneously they are devoid of disadvantages of these systems. Additionally there are a lot of new ideas related to HAPs in early phase. One of the futuristic, however possible, solutions can be e.g. microwave-powered platform [9].

There are plans to set up first commercial HAP based systems in oncoming years [5]. In the short term event services and disaster relief is planned. Benefits from HAP usage will be visible in the medium term in developing countries (e.g. Malaysia). Insufficient terrestrial infrastructure can be complemented with relatively cheap HAPs system. In the long run it is planned the commercial use of multi-HAPs systems. However, all these plans will be finally verified by the market [13].

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