High Altitude Platform Station

A Promising Infrastructure for Delivery of 3G and Beyond 3G Services

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Presentation Outline

• Critical Issues in 3G Implementation
• HAPS Infrastructure for 3G
• Performance of HAPS UMTS
• Technology Trend
Critical Issues in 3G

- Infrastructure difficulties
  - E.g. site deployment, infrastructure sharing
- Lack of new user services for 3G that can’t be supported by existing 2.5G systems (GPRS)
  - E.g. no clear “killer application”
- Difficulties faced in designing and producing the 3G terminals
  - E.g. battery life
Critical Issues in 3G

- 3G *small cell sizes* lead to high system *deployment and maintenance cost*
- To provide *seamless coverage*, 2G system will be required to *bridge the islands* of 3G cells during the initial rollout of 3G services until an alternative solution is available
Issues on Beyond 3G?
Critical Issues in Implementing Beyond 3G Systems

- Beyond 3G (4G) systems are expected to support
  - Wireless LAN
  - Broadband wireless access
  - Point to multipoint communications
  - Multicast/Broadcast services

- 4G systems may need to satisfy
  - High data rate
  - High mobility
  - Seamless coverage
Critical Issues in Implementing Beyond 3G Systems

- The 4G cell sizes may be even smaller than 3G systems => small coverage area
- To provide seamless coverage for mobiles with high data rate and high mobility for the 4G systems using the existing terrestrial tower-based or lamp-post based base stations will result in:
  - high deployment costs
  - high system complexity
  - other fundamental problems similarly faced by the 3G systems
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High Altitude Platform Station

• High Altitude Platform Station (HAPS) is defined in Radio Regulations (RR) No. S1.66A as “A station located on an object at an altitude of 20 – 50 km and at a specified, nominal fixed point relative to the earth”.

Balloons/airships  Unmanned Aerial Vehicle (UAV)  Manned Aircraft
HAPS Applications?
Potential Applications

• Fixed services
  – High speed internet

• Mobile services
  – 3G Mobile (UMTS) at S-band
  – Broadband services at V-band (?)

• Broadcasting Services
  – Digital TV, news gathering

• Other services
  – Remote sensing, radio monitoring, traffic monitoring, weather monitoring

Or may be Combination?
**Frequency Allocations**

- **Fixed services for HAPS:**
  - 47.2 GHz – 47.5 GHz and 47.9 GHz – 48.2 GHz for fixed services
    - allocated in World Radio Conference-97

- **3G Mobile services:**
  - IMT-2000/UMTS
    - Region 1&3 Europe/Africa/Australia/Asia/etc:
      - 1885-1980MHz, 2010-2025MHz and 2110-2170
    - Region 2 USA: 1885-1980 and 2110-2160MHz
HAPS Infrastructure for 3G and Beyond 3G Systems

- The main components of HAPS UMTS are:
  - Platform
  - Energy supply
  - Onboard equipment
  - Ground equipment
Advantages?
HAPS Infrastructure for 3G and Beyond 3G Systems

• 3G/4G services delivered via HAPS are expected to have the following advantages:
  – Can be deployed to serve as the *macrocell component* of the tower-based cells, thus offering a cost effective solution for provision of pico/micro/macro cellular architecture based on *a single air interface standard*
  – Ease the restrictions currently imposed on *site availability* compared to terrestrial
  – More *environment-friendly* than currently used terrestrial macrocells, particularly with regard to the possible *RF radiation hazards*
Centralised architecture improves *efficiency in resource utilisation*,
- i.e. traffic dimensioning can be sized according to the average traffic in the entire service area instead of the busy hour traffic since resources can be shared among all cells
- **Inherent Synchronisation** among different cells
  - due to the possibility of implementing a single timer, allowing faster and softer intra-HAPS handover
- Increase in system capacity is possible through reduction of the cell size by antenna beam shaping.
- **Upgrading of the equipment** can be easily done at a central location.
HAPS Infrastructure for 3G and Beyond 3G Systems

- **Free-space-like** path-loss characteristic
  
  - As HAPS is located at about 22 km above the ground, the propagation path loss is comparable to that at the edge of the small terrestrial tower-based cell with radius of 2 km

- Propagation channels in HAPS are characterised by **Rician** distribution of fade (similar to satellite) whereas in terrestrial tower-based macrocells, fast fades are typically Rayleigh distributed
Major Projects Worldwide

- SkyStation (USA) --airship--
- SkyNet (Japan) --airship--
- SkyTower (USA) --uav--
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Unique Characteristics of HAPS UMTS

Interference depends on antenna radiation pattern rather than the terrain features of coverage area

- Higher system capacity as compared to tower-based systems
- Allows simple and effective forward link power control schemes to be implemented

Base stations are collocated

- Interference can be centrally managed
- Allow implementation of efficient and more superior resource management schemes

All base stations’ transmit antenna beams originate from the same phased array antenna onboard the platform

- The other cell interference are more deterministic
- Allow implementation of efficient and more superior resource management schemes
Performance of HAPS UMTS

• Other cell interference factors

• HAPS UMTS uses good performance antenna.

• Terrestrial tower-based: 0.33 (no shadowing), 0.55 (shadowing).

• HAPS: ~ 0.16

• HAPS UMTS has lower other-cell interference factor than terrestrial tower-based UMTS.
Capacity of HAPS UMTS is \textit{at least 14.4\% higher} than capacity of terrestrial tower-based UMTS.
Performance of HAPS UMTS

• Forward link power control
  • Interference in HAPS UMTS depends only on antenna radiation pattern.
  • Distance based power control schemes can be implemented effectively for HAPS UMTS.
  • Not suitable for shadowed terrestrial tower-based systems because when shadowing is present, distance alone is not a good indication of the power required by the mobile.
Performance of HAPS UMTS

- Forward link power control

Nth-power-of-distance power control provides a capacity improvement of 86%
Call Admission Control?
Performance of HAPS UMTS

- Centralised total received power based call admission control
  - In HAPS UMTS, all base stations are collocated.
  - Information on current interference conditions can be exchanged between base stations with minimal signalling overheads and delay.
  - Distributed global CAC schemes proposed for terrestrial tower-based UMTS can be implemented more efficiently for HAPS.
  - In fact, more integrated, i.e., centralised CAC schemes can be implemented so that interference is managed centrally rather than at individual base stations.
Performance of HAPS UMTS

- Centralised total received power based call admission control

**GoS = \( P_b + 10P_d \)**

**CRP-RA**: Centralised Received Power Based Random Model CAC. Calls are processed in a random order.

**CRP-RK**: Centralised Received Power Based Ramking Model CAC. Gives priority to call requests to a cell with the lowest total received power

Centralized schemes outperform the global distributed scheme
Performance of HAPS UMTS

- Centralised transmit power based call admission control scheme
  - All base stations’ transmit antenna beams originate from the same phased array antenna onboard the platform.
  - BSs can share the limited power resource available onboard the HAPS.
  - Calls blocked if total platform power exceeds an allowable platform power limit (CTP-PF).
  - CTP-PF scheme outperforms the CTP-BS scheme

\[ \text{GoS} = P_b + 10P_d \]
Performance of HAPS UMTS

- Centralised transmit power based call admission control scheme

  - CTP-PF scheme requires only approximately 24% of the total platform power required by the CTP-BS scheme to achieve the same levels of GoS.

- CTP-PF: Platform output power sized to handle the peak power requirement of the entire service area.

- CTP-BS: Base stations’ output powers must be sized to handle the respective base stations’ peak power requirements.
Handover?
Performance of HAPS UMTS

- Speed and direction adaptive softer handover schemes
  - The difference in received downlink common pilot signals (CPICH) from a mobile’s serving base station and its neighbouring base stations are basically the difference in antenna gain
  - This antenna gain difference is deterministic and can be used to track the mobile’s relative travelling speed and direction
• Speed and direction adaptive softer handover schemes
  • $ROC_{\Delta \text{pilot}} = |\Delta \text{pilot}_{t1} - \Delta \text{pilot}_{t2}|/\Delta t$ where $\Delta t$ is the difference between $t1$ and $t2$
  • Mobiles with a higher $ROC_{\Delta \text{pilot}}$ should be allowed to establish softer handover first in order to avoid calls being outaged while the mobiles are moving quickly toward the cell edge where interference is most severe
Performance of HAPS UMTS

- Speed and direction adaptive softer handover schemes

Grade of service \( (GoS = P_b + 10P_d) \)

- ADS1: Only add margin is adaptive
- ADS2: Both add and drop margins are adaptive
- NADS: Non-adaptive (fixed add and drop margins) scheme

The adaptive schemes outperform the non-adaptive scheme in \( GoS \)
In short?
Performance of HAPS UMTS

- HAPS has the potential to deliver 3G and beyond 3G services in a more *spectrally efficient* and *cost effective* way
- HAPS’s unique interference characteristics allow *higher system capacity* to be achieved
- The centralized architecture inherent in HAPS allows the implementation of more *efficient and effective resource management* schemes that are seen to be impractical or impossible for terrestrial tower-based systems
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Technology Trend

- HAPS will be deployed together with terrestrial and satellites elements to provide another degree of *flexibility for system deployment* that can be easily adjusted to the needs of the network operators and users’ traffic demands.

- HAPS will play a complementary role in future mobile system infrastructure e.g. consisting of W-LAN, cellular, and satellite mobile systems *to ease the deployment* and roll out of the 3G and beyond 3G services.
Technology Trend

- Mobile Communications Research Group
- Centre for Communication Systems Research

Diagram showing communication links between a satellite ground station, HAPs (High-Altitude Platforms), and an UMTS (Universal Mobile Telecommunications System) network. The diagram highlights SAT-HAPS links, Inter HAPS links, HAPS backhaul links, and UMTS Core Network.
Conclusions

• HAPS can overcome some critical issues in 3G (and beyond 3G) implementation
• The HAPS infrastructure for 3G has several advantages over terrestrial
• It has been shown that HAPS UMTS gives capacity and resource management improvements
• The technology trend shows HAPS playing a complimentary role to the existing infrastructure