WLAN-3G Interworking

Mohammad Abualreesh , Helsinki University of Technology

Abstract— **Advanced wireless mobile communication systems such as UMTS provide users high mobility but less bandwidth. On the other hand, Wireless LAN systems offer high bandwidth with less mobility. However, there is a need for public wireless access: to cover the demand for high data-intensive applications and to enable smooth online access to corporate data services in hot spots. Therefore, one possibility to supply this need could be achieved through interworking between both technologies, i.e., UMTS-WLAN interworking together. Here, in this paper we present the main issues of the UMTS-WLAN interworking approach: features, aims, development, methods, analysis, and evaluation.**

Index Terms— **UMTS (Universal Mobile Telecommunication System), WLAN (Wireless Local Area Network), WCDMA (Wideband Code Division Multiple Access).**

I. INTRODUCTION

There has been a huge development in wireless communication technologies: in both of mobile technology and WLAN technology. Mobile technologies such as GSM, GPRS, and UMTS offer high mobility but with low rates (2Mbps rates has not been achieved yet). In contrast, WLAN technologies offer high rates such as 11Mbps, 54Mbps and more but the mobility available in WLANs is low. Therefore, one thing could be highlighted here, is that why we don not utilize the benefits of both technologies and combine them together to address new generation technology that covers the increasing user demands. Moreover, there is a need for public wireless access: to cover the demand for high data-intensive applications and to enable smooth online access to corporate data services in hot spots. This need could be covered as proposed in Figure1, where both mobile cellular systems and WLAN systems are to be interworking together.

This direction is enhanced when looking at Figure2 which indicates that in the 3G evolution path very high data rates are achieved in hot spots with WLAN rather than cellular-based standards.

As a result, a new aimed target has been desired to be achieved in the future to enable new high data rates available to the end user. This comes as an aimed target for 4G, beyond 3G, to support at least: 100 Mbps peak data rates in full-mobility wide area coverage, and 1 Gbps in low-mobility local area coverage.

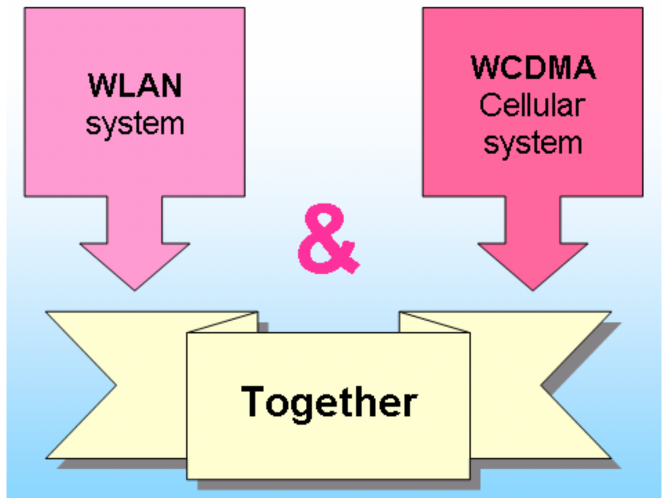

Figure1 *Proposal of interworking both mobile cellular systems and WLAN systems together to utilize the benefits in both systems to cover the increasing user demands.*

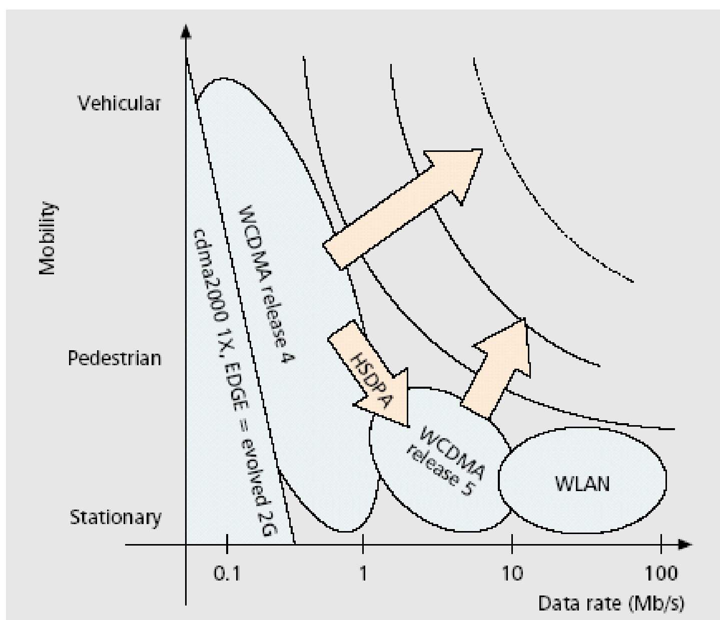

Figure2 *Data rate trends*

II. WCDMA AND WLAN FOR 3G AND BEYOND

WCDMA has been designed to support future applications requiring simultaneous transmission of several bit streams that require individual quality of service (QoS). The WCDMA air interface was initially designed to support a wide variety of services with different QoS requirements having a maximum bit rate of 2 Mb/s. In order to satisfy the future service and application needs several technical enhancements are being studied and standardized for WCDMA in 3GPP. Even with evolved WCDMA, there is a need for another public wireless access solution to cover the demand for data-intensive applications and enable smooth online access to corporate data services in hot spots.

As development objectives, the development of 3G will follow a few continuing key trends: increasing capacity optimization for voice services, increasing IP-based applications, supporting simultaneous voice and data improving data services efficiency, delay, and average and peak user data rates, making more attractive multimedia terminals to be spread out everywhere, achieving high-quality high-data-rate everywhere, and finally decreasing cost to be affordable for everybody.

However, WCDMA comes as an answer to the expected trends in the 3G development objectives, mentioned above. The answer of WCDMA evolution view, from release 99 and release 4 (March 2001) to beyond 3G, can be seen in three phases as described next.

In Third Generation Project Partnership (3GPP) standardization phase 1 is already in progress; the other two phases try to highlight future potentials, but such development has yet to be seen in 3GPP standardization.

Phase 1: High-Speed Downlink Packet Access —

In the first phase, the peak data rate and throughput of WCDMA downlink for best effort data will be greatly enhanced when compared to release 99. In 2001, the specification of high-Speed Downlink Packet Access (HSDPA) was completed in 3GPP release 5. Focusing on enhancement of the high-speed downlink shared channel (HS-DSCH). The main proposed technical enhancements of HS-DSCH include:

- Adaptive modulation and coding (AMC)
- Fast hybrid automatic repeat request (FHARQ)
- Fast cell selection (FCS)

AMC is a radio link adaptation technique where the modulation order and channel coding method are varied according to the quality of the received signal. AMC is sensitive to measurement errors and delays; therefore, FHARQ has been proposed to provide implicit link adaptation to instantaneous channel conditions. FCS has been proposed to potentially decrease interference and increase the capacity of the system.

As a result, the peak data rate of HS-DSCH will be about 10 Mbps and the throughput of a cell/sector will be doubled when compared to release 99. Phase 1 (Release 5) will include some basic solutions AMC and FHARQ HSDPA for TDD mode technical improvements.

Phase 2: Uplink High-Speed Data, High-Speed Access for TDD —

In phase two, the emphasis will be on Uplink High-Speed Data and High-Speed Access for TDD. Here, enhanced data rates in the uplink will benefit the end user. Also, an optimized uplink can be designed to support lower terminal output powers. Additionally, further improvements of HSDPA for both FDD and TDD modes will be seen.

Phase 3: Capacity Improvements in Uplink and Downlink, Further Data Rate Enhancement —

There will be some unacceptable issues for the proposed phases 1 and 2 of WCDMA development; so further enhancement will be introduced in later phases. Here, there will be Capacity Improvements in Uplink and Downlink, and further enhancement of WCDMA data rates up to significantly above 10 Mbps.

Phase 1 of WCDMA evolution was completed in 2001. While, for later phases there is no approved work plan exist, as illustrated in the time frame shown in Figure3.

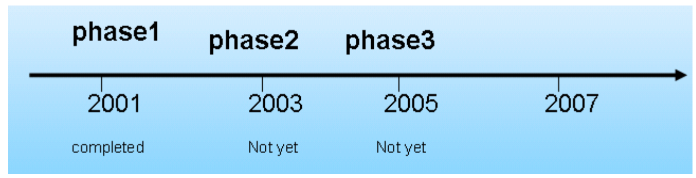

Figure3 *Time proceeding of the 3G development phases.*

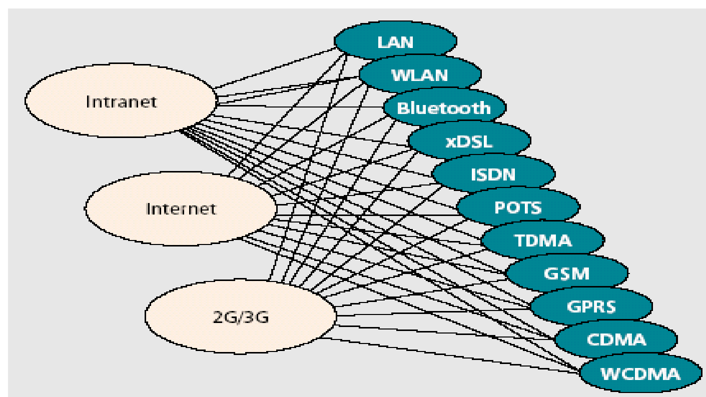

Figure4 *Coupling of air interface technologies to the network.*

Another possibility

Another possibility could be used as another technology to be considered for hot spot coverage is the UMTS Terrestrial Radio Access Network (UTRAN TDD) mode, which is well harmonized with WCDMA FDD and in such a way facilitates cost-efficient dual mode terminal design.

4G

As a continuous development beyond 3G, 4G comes where one major trend in 4G is to have more and more higher speeds than in 3G. 4G is seen as a revolution of the air interface rather than a new phase of evolution. Remind the aimed target for 4G to support at least: 100 Mbps peak data rates in full-mobility wide area coverage, and 1 Gbps in low-mobility local area coverage. The other major trend is that access methods will be less tightly coupled to the network, see Figure4.

Figure5 illustrates the evolution of 2G/3G cellular and WLAN standards and the revolutionary step toward future wireless systems. Here, the evolution of GSM has been maintained in parallel of the evolution of WCDMA and WLANs.

Spectrum

As a spectrum organizing issue, WRC2000 already identified new spectrum for IMT-2000 systems. The ITU identifies frequency range at 2 GHz. In addition to 2 GHz identifications, WRC2000 also identified parts of the 806–960 MHz band that already have primary mobile allocations to IMT-2000. The spectrum allocation is illustrated in Figure6.

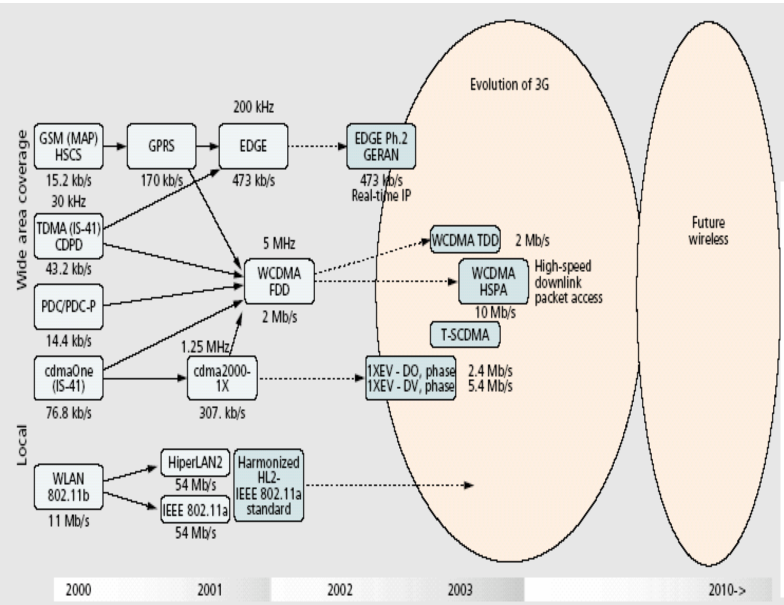

Figure5 The path toward 4G from a radio perspective. The time axis shows the estimated launch times of the actual systems.

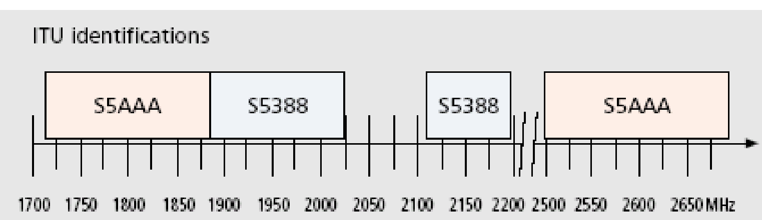

Figure6 *ITU spectrum identification: S5.388 is the WARC '92 identifications, and S5.AAA is the additional WRC 2000 identifications.*

III. UMTS-WLAN INTERWORKING STRATEGIES

To implement the previous discussed issues above, three approaches for UMTS-WLAN interworking have been proposed:

Mobile IP Approach
Gateway Approach
Emulator Approach.

Mobile IP Approach

This interworking strategy is to use mobile IP. Figure7 shows the protocol architecture.

In this approach UMTS and WLAN are peer- to- peer networks. In the UMTS network, user equipment UE uses standard UMTS session management (SM) and GPRS mobility management (GMM) to handle a packet data protocol (PDP) session and the roaming between WCDMA radio access networks. While, in the WLAN the UE uses IP directly. As for the mobility management in WLAN, mobile IP might be also used. If a UE decides to handover from UMTS to WLAN, it simply disables its UMTS protocols and uses the IP stack. If the UE wants to use the same IP address that uses in the UMTS network or wants to be accessed via the original IP address, mobile IP should be involved. Foreign agents and home agents FA/HA are installed in the WLAN access router (AR) networks and GGSN networks so that FA/HA can help routers to tunnel and forward the data packets.

Generally speaking, the existing mobile IP and UMTS standards are quite enough and mature to support this approach. However, the handover latency and the packet lose

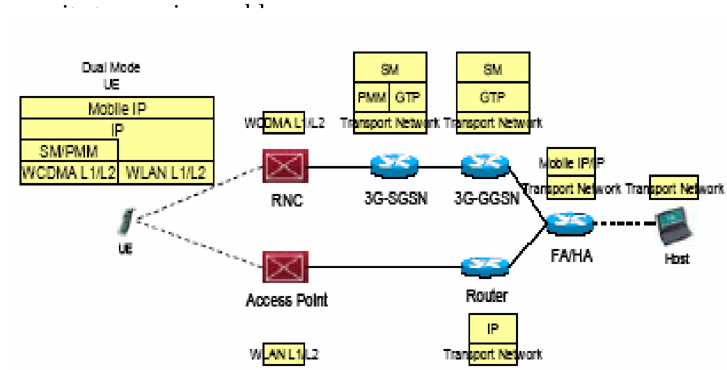

Figure7 *The protocol architecture of the mobile IP approach.*

Gateway Approach

The second approach is to use a gateway to interconnect the two networks. Figure8 shows the protocol architecture. Here, UE uses standard SM and GMM to access the UMTS network and uses the standard IP to connect to the WLAN. In the WLAN, the UEs might use mobile IP to handle the mobility within the WLAN. For users wish to have interworking services, the control signals and data packets are be routed through the gateway. If the two network operators have a roaming agreement, the gateway enables the intersystem roaming of the two networks.

The merits of this approach are that the two networks can be operated independently and mobile IP is not necessary.

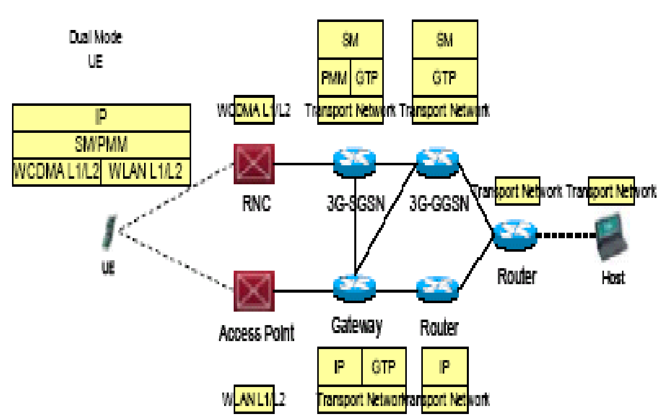

Figure8 The protocol architecture of the gateway approach.

Emulator Approach

This approach is to use WLAN as a UMTS access stratum (AS). Figure9 shows the protocol architecture. Here, the session management and the mobility management are handled by the UMTS SM and GMM. The UE cannot access Internet through WLAN directly. This approach tightly couples the two networks and WLAN can be viewed as a slave network of the UMTS.

The advantage of this approach is that the handover latency is much lower than other two approaches. However, every packet should pass through GGSN, which becomes the bottleneck.

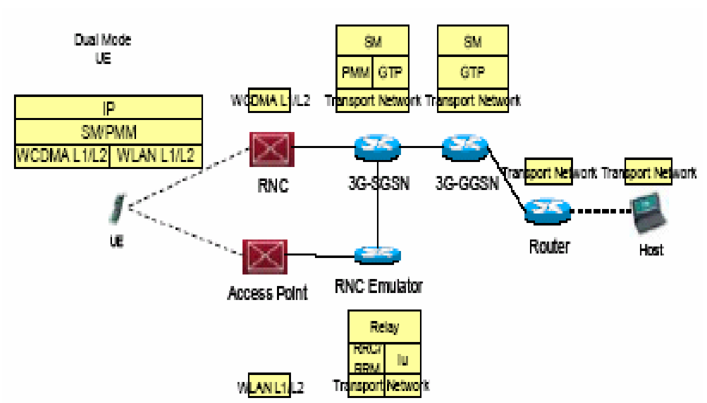

Figure9 *The protocol architecture of the emulator approach.*

IV. PERFORMANCE AND EVALUATION

In this section, we present some performance and evaluation for the UMTS-WLAN interworking approach based on simulation, for more about that one can refer to reference [3].

Part1

The simulation environment has a UMTS network and a WLAN using NS2 developed by UC Berkeley for this simulation. The UMTS network has 100Mbps backbone with 5 radio network subsystems and offers 32Kbps data services. WLAN has 25 access points and provides 100Kbps data service. Assuming 50% users are WLAN users and the other 50% users are UMTS users. Among all users, 50% are dual mode users and might moves in between two networks, and the other 50% are single mode users using either WLAN or UMTS. Dual mode users have a 0.5 probability to enter the WLAN and a 0.5 probability to enter the UMTS.

The three different approaches are compared here, i.e. mobile IP, gateway and emulator approaches.Figure10 shows the handover latency. From which, it is clear that mobile IP obtains the poorest performance since the signaling packets have to go to Internet (home agent and foreign agents). Gateway and emulator approaches only involve the message exchange within intra-network. The latency of gateway approach is a little bit higher than the emulator approach.

We also learn that mobile IP approach will introduce more than 200ms latency under this network configuration while the users are more than 2000. The latency might not be acceptable for real-time applications.

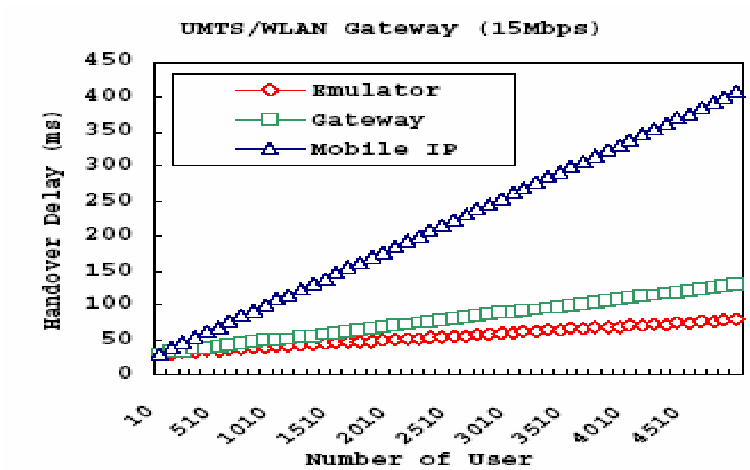

Figure10 *Handover latency of different UMTS/WLAN interworking strategies.*

Part2

Here channel data from a 3D site-specific propagation model together with physical layer and system-level simulation tools have been used to simulate the coverage, throughput, and capacity of an integrated 3G/hotspot system in an urban microcellular environment. The BS and AP locations are optimized using a site optimization algorithm, and two cases are examined for the hotspot overlay: the first involved 3 APs, and the second made use of 15 APs. 7 UMTS BSs with 90% coverage. A frequency allocation algorithm is used with (C/I) of 10 dB. The UMTS is performed at 2 GHz, assuming omnidirectional antennas located at a height of 5 m and with a transmit power of 30 dBm. The HIPERLAN/2 WLAN hotspot overlay is performed at 5 GHz, with omnidirectional antennas at a height of 5 m and AP transmit powers of 23 dBm and 30 dBm. The mean rms delay spread in the vicinity of AP1 = 55 ns. The 3G simulation assumed a 3.84 Mchipps UMTS terrestrial radio access (UTRA) time-division duplex (TDD) type system. Three user classes are considered: for 3G: class 1 users support voice at 15 kb/s, class 2 users support data at 144 kb/s, and class 3 users support data at 384 kb/s. Users are uniformly deployed in the 1 km × 1 km area of Bristol University. See Figure11.

Hotspot physical layer provides several modes, each with a different coding and modulation configuration: mode 1: binary phase shift keying (BPSK) 1/2 rate; mode 2: BPSK 3/4 rate; mode 3: quaternary PSK (QPSK) 1/2 rate; mode 4: QPSK 3/4 rate; mode 5: 16- quadrature amplitude modulation (QAM) 9/16 rate; mode 6: 16-QAM 3/4 rate; mode 7: 64-QAM ¾ rate. A link adaptation scheme has been used in which the mode with the highest throughput is chosen for each instantaneous SNR value.

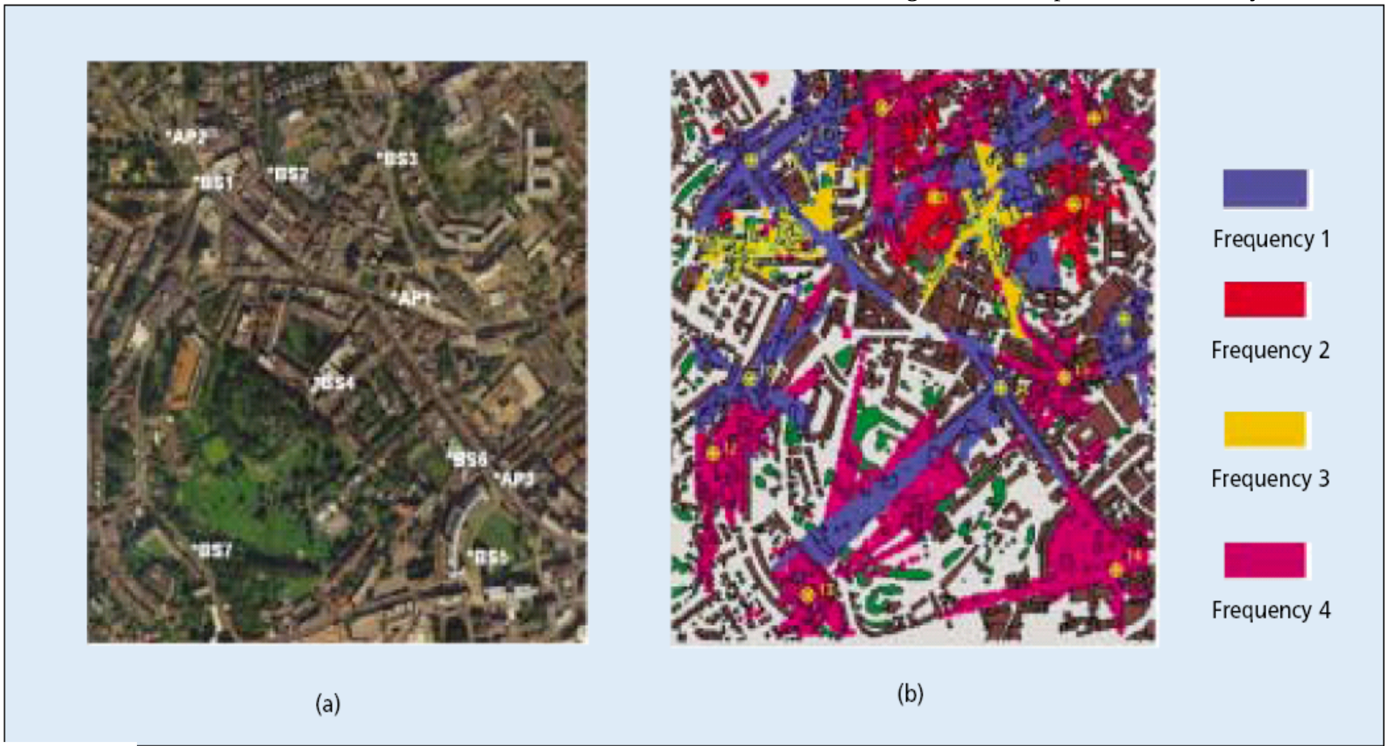

Figure11 *a) Locations of seven BSs and three APs; b) locations and example frequencies for 15 APs.*

Coverage, throughput, and transmission mode distribution maps are produced for the different cases, including results for both HIPERLAN/2 and IEEE 802.11a with variable AP transmit powers. See next Figures 12-17. It can be seen that at higher data rates the HIPERLAN/2 standard covers a larger area than IEEE 802.11a. As expected, 15 APs are shown to cover a large proportion of the network area, and high peak rates (up to 42 Mb/s) are available at many locations. Overall, hotspot data support is considerably higher than even the highest 3G rates.

Capacity has been shown to significantly increase when interworking between hotspots and 3G networks is employed.

This is particularly true when a high percentage of the area is covered by the hotspot network. It is shown that over 1000 extra connections can be supported in a 1 km × 1 km area when 15 WLAN hotspots are deployed alongside the 3G network. See Table1.

V. Conclusion

The WCDMA air interface is seen to develop far beyond its initial capabilities to satisfy future service and application needs. WLAN systems are seen to complement WCDMA-based cellular evolution in hot spots in development beyond 3G.

The other technology to be considered for hot spot coverage is UTRAN TDD mode, which is well harmonized with WCDMA FDD and in such a way facilitates cost-efficient dual mode terminal design.

4G needs to be something that 3G evolution cannot do. 4G should support at least 100 Mbps peak rates in full-mobility wide area coverage and 1 Gbps in low-mobility local area

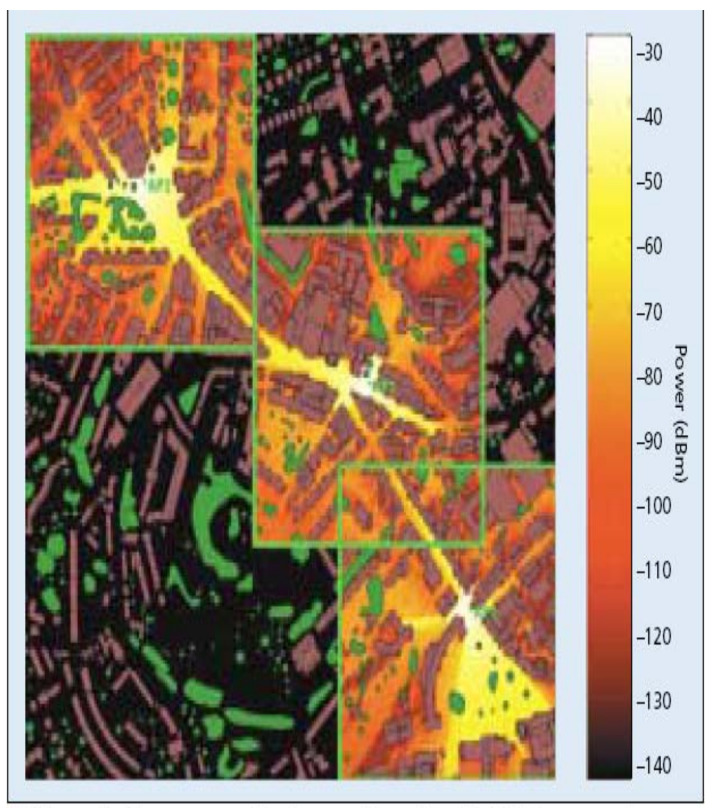

Figure12 *Coverage map for three outdoor APs with 30 dBm transmit power.*

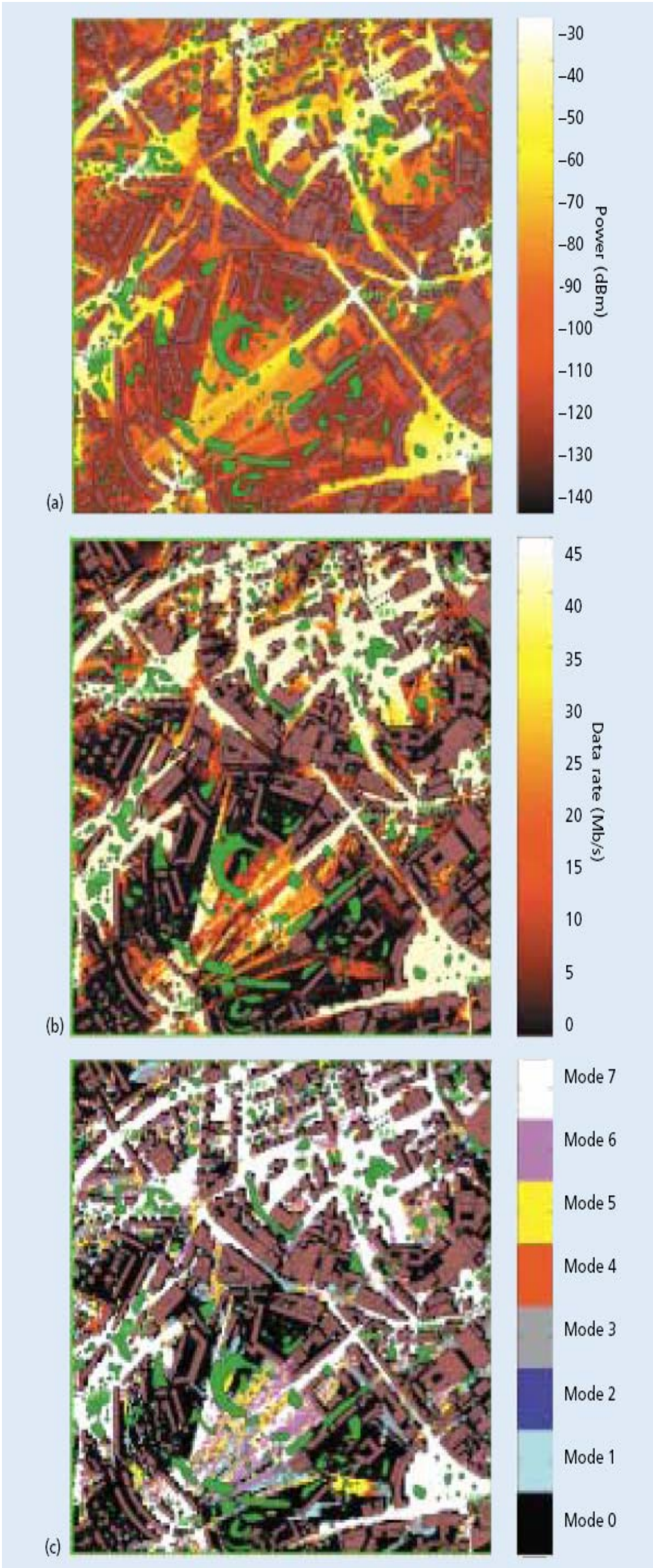

Figure13 *a)Coverage; b) throughput; c) mode distribution for 15 HIPER-LAN/2 APs with 30 dBm transmit power.*

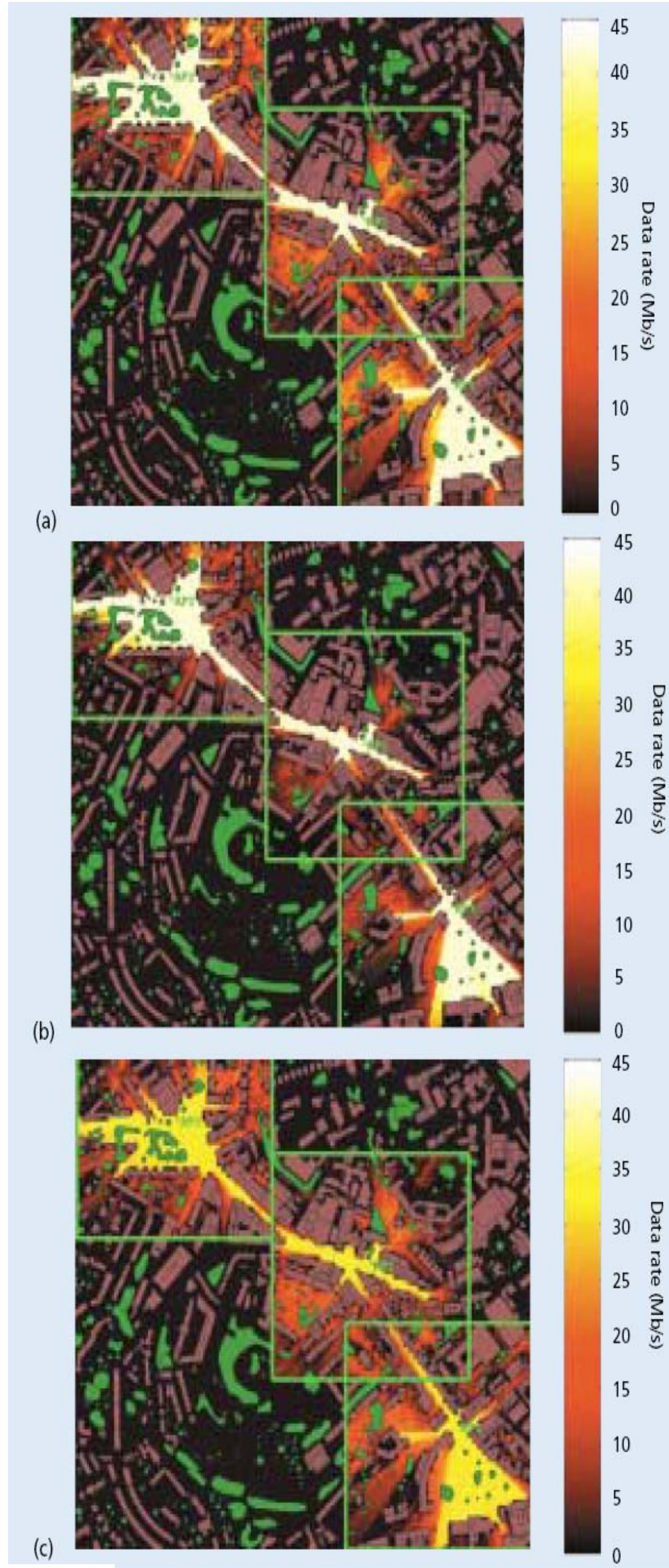

Figure14 *Throughput map for a) HIPERLAN/2, 30 dBm transmit power; b) HIPERLAN/2, 23 dBm transmit power; c) IEEE 802.11a, 30 dBm transmit power and 1500-byte packets.*

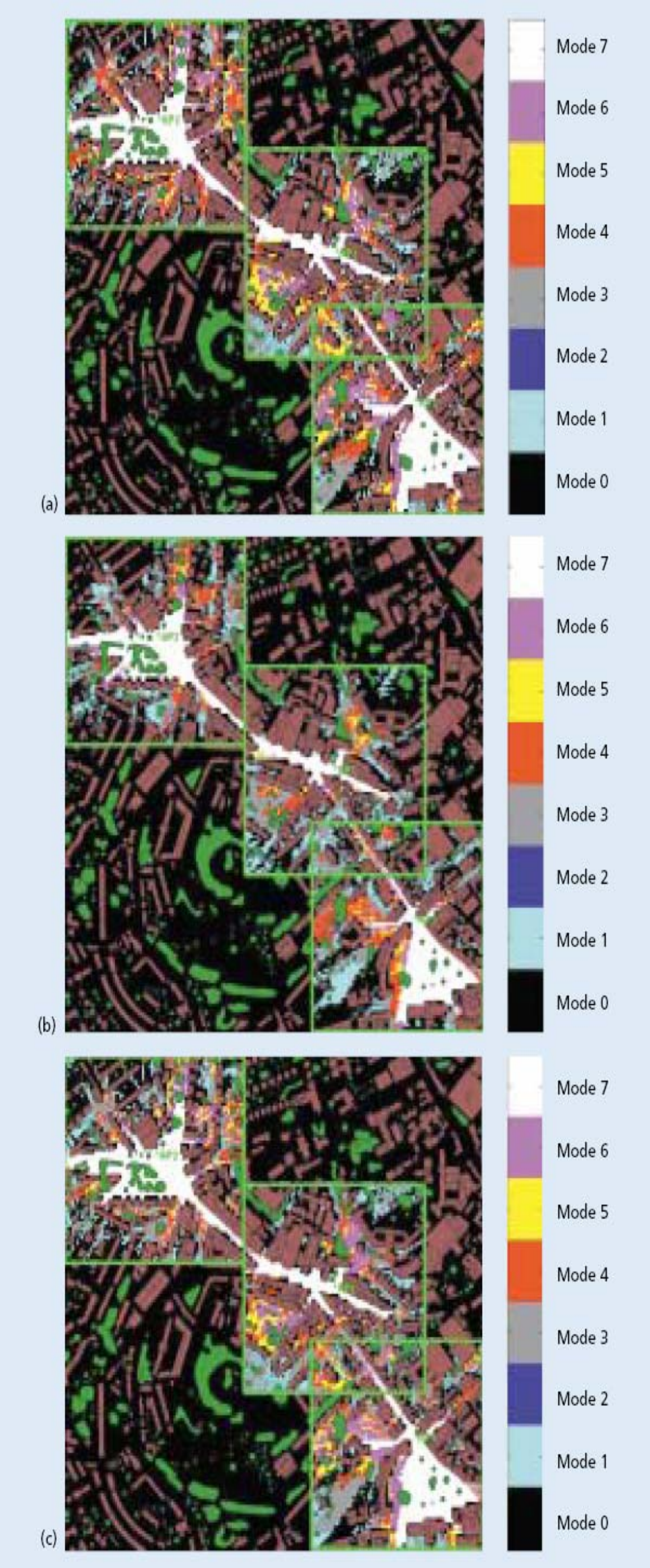

Figure15 . *Mode map for a) HIPERLAN/2, 30 dBm transmit power; b) HIPERLAN/2, 23 dBm transmit power; c) IEEE 802.11a, 30 dBm transmit power and 1500-byte packets.*

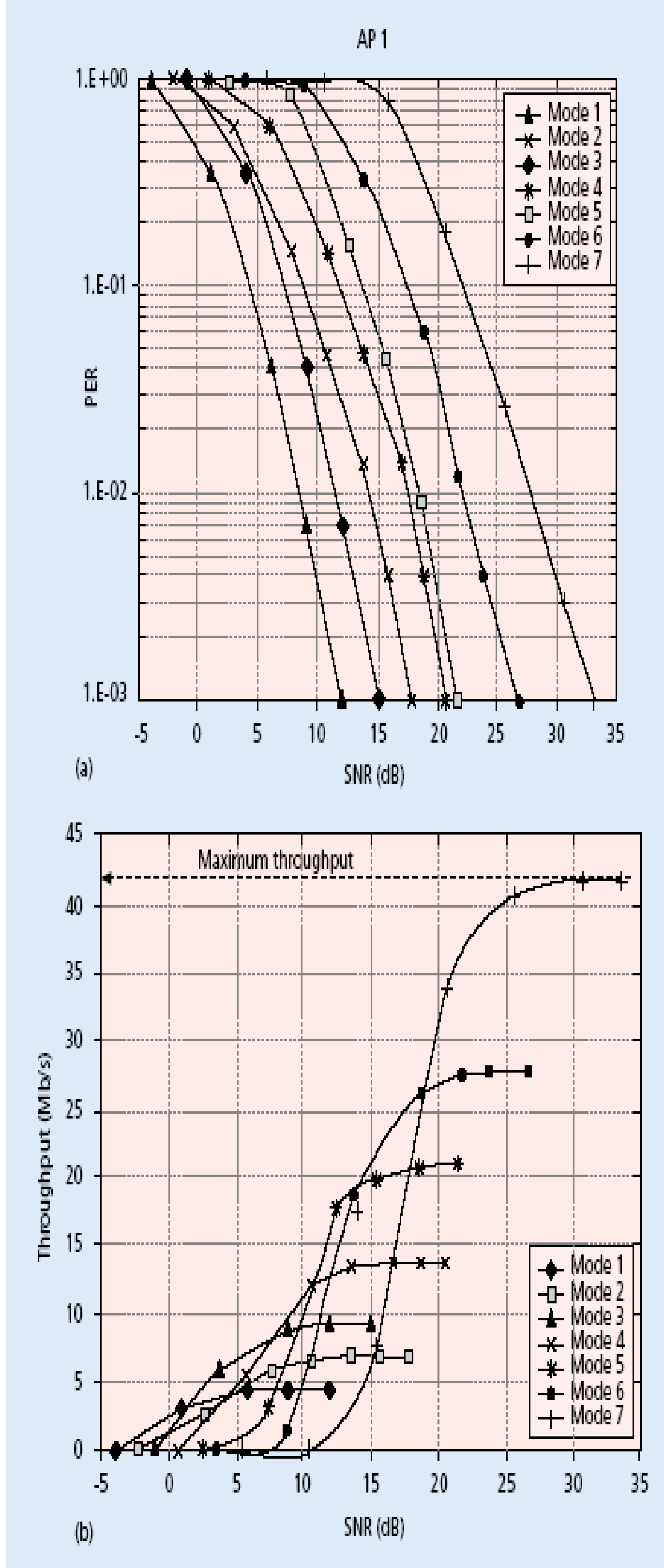

Figure16 *a) PER performance; b) throughput vs. SNR of AP1 for HIPERLAN/2.*

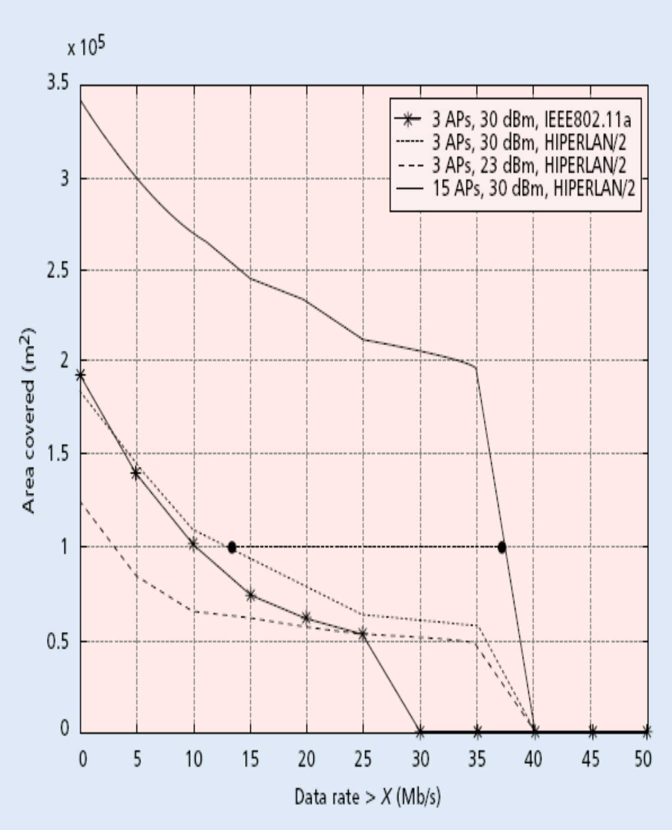

Figure17 . *Throughput area distribution comparison.*

Scenario	WLAN connections /AP			WLAN SE (b/s/Hz/AP)	3G users per BS		
	144 kb/s	384 kb/s	2 Mb/s		15 kb/s	144 kb/s	384 kb/s
3 APs, EIRP = 30 dBm 2 Mb/s on WLAN	33	16	5	1.16	16	4	1
3 APs, EIRP = 30 dBm no 2 Mb/s on WLAN	64	25	0	1.15			
3 APs, EIRP = 23 dBm 2 Mb/s on WLAN	28	13	4	1.0			
3 APs, EIRP = 23 dBm no 2 Mb/s on WLAN	49	24	0	0.98			
15 APs, EIRP = 30 dBm, 2 Mb/s on WLAN	47	22	6	1.68			
15 APs, EIRP = 30 dBm, no 2 Mb/s on WLAN	82	40	0	1.65			

Table1 *Capacity for3G-WLAN system*

Mobile IP approach is the easiest deployment strategy and the standards to implement the interworking are ready. However, the simulation results show that it suffers from long handover latency and might not be able to offer real-time services and applications. The improvement of handover speed is one the most important future work of this approach.

The gateway approach obtains a much lower latency than mobile IP approach. It helps the two networks to operate independently and also provides the capability of the intersystem roaming. This approach is applicable to the current network environment.

From the service and applications point of view, the above two strategies cannot provide the service and application mobility, e.g. to carry over location based service in UMTS to WLAN users. And so the emulator approach achieves the best performance in terms of handover latency. However, the management and procedures in the radio network control side of the WLAN need to be further studied. Moreover, this approach lacks of the flexibility since the two networks are tightly coupled.

In hotspot-3G interworking, to take advantage of such interworking, users are required to use dual mode terminals. This allows users to combine higher data rates in the hotspots with continuous coverage and high mobility via the cellular network.

In dense urban areas where high populations require extra capacity, hotspots can be deployed to enhance data rates and relieve cellular congestion.

Finally, UMTS-WLANs interworking is still under research and needs more study and development which hoped to available in the near future as promised by the technologies developers.

HOMEWORK

Why do we need a public wireless access? How it could be achieved?

What are the 3G development objectives? How does WCDMA answer these objectives (no details are needed here)? What is the final aimed goal to be achieved by 4G?

What are UMTS-WLAN interworking strategies? State the main comparison features of these strategies. No details are required here.

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