Cooperative Networks for 4G

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Introduction:

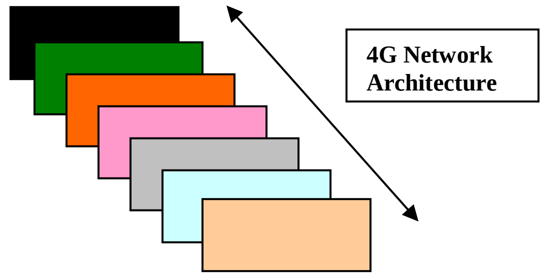
The motivation of this paper is the delay between the technological inventions and their actual deployment in real world. Particularly referring to the emergence of 2.5G technologies which provided features like GPRS, EDGE. In spite of 2G being a huge success story, the future generation of mobile technologies could not recreate its magic. 2G could enhance the standard of living of a common man by empowering him with a device which could allow him to reach anyone in the remotest corner of the world. Its main strengths were high quality of speech and global mobility. 3G failed to entice due to its limited additional features like Multimedia Broadcast and Multicast Service Center (MBMS) in combination with the IP Multimedia System (IMS).[1] But these technologies failed to tune the correct access technology. The advent of 4G promises to go beyond these technologies and provide state of art services like pop up window on the mobile device or connecting other devices, (not limited to mobile phones), like computers to facilitate better utilization of resources and better Quality of Service(QoS) for users.

This paper is divided into three sections. The section one clarifies the definition of 4G, section two introduces the cooperative networks and services concepts which increases the QoS and the third section deals with the layered architecture for 4G technologies.

Defining 4G

4G will be a convergence platform which will provide clear advantages in terms of bandwidth, power consumption, spectrum usage and a mix of heterogeneous services which can be integrated across various networks designed with a basic cellular architecture. This core architecture when extended can provide mechanisms for users to cooperate to enhance their utility, over short range of communication. The goal is to provide enhanced level of integrated services along with increases spectral efficiency and QoS. Cooperative network architecture is built on the cellular framework for this purpose.

The past technologies dint serve the purpose of matching pace with increasing user's perspective of utility in the sense that it involved design of services only at application in physical layer. Due to this methodology adopted the find tuning of intermediate layers would create a hindrance in the implementation of the services designed. The aim of 4G is to integrate design and functionality at all levels of protocol architecture and hence provides full potential to realize the needs of the users.



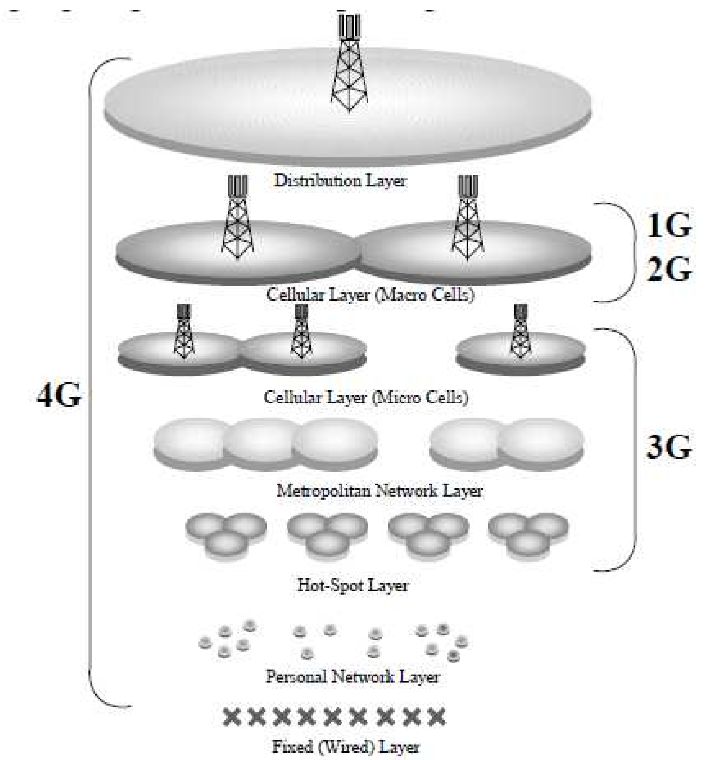
4G also aims at providing personalized user services. This demands higher understanding of user's expectations. The key features of 4G are implementation of user personalization, deploying heterogeneity in terms of network, terminal and services, evolutionary design of devices and personalized content on mobile devices. [2]

1. User Personalization

In order to make 4G succeed where 3G hasn't, is to provide user friendly services with user personalization. It is important for the user to be able to fully access the features of the phone and use it for novel applications like live video streaming, interactive services, IP data casting[3].Also users can be provided a personalized applet which will allow them to choose the services available to them and access any information on the fly. Social life play can important part in a person's life and hence it is important to have a deeper understanding of human requirements in order to enhance his social life.

2. Deploying Heterogeneous Services

Heterogeneous services imply that users can access information by connecting to one or more types of networks. This heterogeneous connectivity can be made possible by dynamic nature of the terminals and topology of the network. For example if the user cannot access the WLAN he is subscribed to, he can still access the required content by the setting up a multi-hop ad hoc network on the fly. Also short range communication technologies like Wi-Fi and Bluetooth will enable communication between various devices. Universal Mobile Telecommunication System (UMTS) and digital audio/video broadcasting (DAB/DVB) will open the possibility to provide to mobile users interactive or on demand services — so called IP data casting.[3]



3. Multimode Reconfigurable Devices

The user terminal is able to access the core network by choosing one of the several access networks available and to initiate the handoff between them without the need for network modification or internetworking devices. This leads to the integration of different access technologies in the same device (multimodality) or to the use of the software-defined radio (SDR) (reconfigurability) [4]. For example, whereas the integration of Bluetooth in the user terminal will enable a personalization-transfer service, a built in GPS receiver will allow users to utilize their personal devices as navigators just by plugging them in their cars and thus even lighten the number of needed devices. However, the reconfigurability of the user terminal could be a key aspect that would make the future 4G technology as highly adaptable as possible to the various worldwide markets.

Data transfer capability	▪ 100 Mbps (wide coverage) ▪ 1 Gbps (local area)
Networking	▪ All-IP network (access and core networks) ▪ Plug & Access network architecture ▪ An equal-opportunity network of networks
Connectivity	▪ Ubiquitous ▪ Mobile ▪ Seamless and Continuous
Network capacity	▪ 10-fold that of 3G.
Latency	▪ Connection delay < 500 ms ▪ Transmission delay < 50 ms
Cost	▪ Cost per bit: 1/10-1/100 lower than that of 3G ▪ Infrastructure cost: 1/10 lower than that of 3G
Connected entities	▪ Person-to-person ▪ Person-to-machine ▪ Machine-to-machine
4G Keywords	▪ Heterogeneity of networks, terminals and services ▪ Convergence of networks, terminals and services ▪ Harmonious wireless ecosystem ▪ Perceptible simplicity, hidden complexity ▪ Cooperation as one of its underlying principles.

4G Challenges

Although 4G is considered the future of enhanced wireless world, there are many challenges existing to make this dream a reality. A global standardized approach to 4G is required. There are too many divergent approaches in which 4G is defined. Inter-network and intra-network connectivity is fundamental to the provision of temporally and spatially seamless services. Vertical and horizontal handovers are critical for 4G. In the former case, the heterogeneity and variety of networks exacerbate the problem. Many 4G services are delay sensitive. Guaranteeing short delays in networks with different access architecture and coverage is far from straightforward. User centric approach seems the most logical approach to 4G, developing technology based on the user needs and expectations. The further in the future 4G is, the higher the risks on the user expectations predictions. Non conventional access architectures may need to replace conventional ones in many scenarios. More studies need to be conducted on these approaches. 4G networks would be undoubtedly complex, but this complexity needs to be hidden from the user. Management of time, frequency and spatial resources in a multi-network, multi-user environment is far from trivial. Multiple access interference control and mitigation in heterogeneous environments (coexisting air interfaces, varied terminals and services) is an issue. By any measure, power consumption in future multi-function multi-standard 4G terminals will sharply increase. Usability is seriously compromised, heat management becomes an issue. Cost of infrastructure is key for the success of 4G. However, new access architectures may require a large number of access points. Cost of terminal should be low enough to attract customers. Services need to be attractively priced.

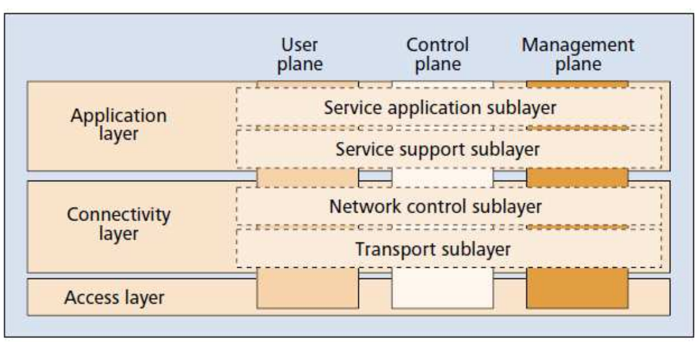
Architectural Design

This section describes architectural principles and basic requirements of a 4G Network. These features mainly include functional blocks, multiple services and their creation, connectivity issues, end-to-end concept, security, control, operation and maintenance, and self organization

In Cooperative Networks (CoNet) [6], a *layered* approach is globally supported. This means that the functionality of the system is grouped into distinct layers that form logically separate subsystems. Any layered model has at least three layers: application, connectivity, and access. The application layer can be further divided into service application and service support sub layers. The connectivity layer can be further divided into network control and transport (IP) sub layers. And the access layer may contain several independent access networks that can also function simultaneously. The layers should have well defined interfaces and be functionally independent of each other. Such an approach is required to ensure easy adaptation of heterogeneous access technologies, related technology changes, and flexible support for rapid service innovation. Because of the need for cross-layer optimization (e.g., for power management, QoS support, etc), the layered approach in CoNet is considered as a design principle rather than as a universal design pattern, meaning that every 4G system may potentially have its own layered architecture.

Independent Functional Blocks, Modularization and Reuse

The CoNet architecture should define each function as an independent functional block. This promotes component-based modular architecture, where different building blocks can be combined as needed to realize complex systems. This in turn requires standardized definition of
syntax and semantics of these interfaces. For instance, functionalities required to process and route user data, handle control signaling, and deal with network management can be separated into different functional blocks in the user, control, and management planes, respectively. It should be noted that each layer of the architecture has its own separate set of functions for each plane; hence, nine different functional blocks can be identified. Realization of the functionalities as independent building blocks allows the introduction of new functions when needed without changing
the whole architecture. The building blocks should be reused, when applicable, with different access technologies and realization of various services. Therefore, implementing the same or very similar functionality multiple times should be avoided.



Cooperative Connectivity

The CoNet architecture should ensure connectivity between all the entities of a network in a consistent manner across all access technologies for any service. This requires consistent support for device mobility, QoS, authentication, authorization, and accounting (AAA) and so on. The connectivity layer provides cooperation across various realizations of networks, called *cooperative connectivity*, and shall be independent of the various transport technologies used to link the nodes of the network together. By separating access and transport the CoNet architecture makes it transparent to the common and standardized transport infrastructure and hides the technology from the end user, while facilitating the most efficient usage of spectrum resources. The CoNet architecture shall support both session continuation (i.e., handover when
the access technology used is changed) and simultaneous usage of several access networks. Finally, the user should be able to seamlessly roam across different access technologies and administrative domains without any manual user intervention. This implies that the CoNet architecture should also support connection of subscribers to private IP networks through Network Address Translators (NATs) and Simple Traversal UDP through NATs (STUNs).

An End- To – End Approach

The CoNet architecture should include the endpoints (i.e., terminals) as part of the communication system, and support end-to-end (E2E) negotiation and fulfillment of QoS parameters, security settings, and so on. This E2E approach does not mandate that all functionality should be located in the endpoints. On the contrary, the functionality can also be provided in hop-by-hop, and/or edge-to-edge manner subject to proper and lawful termination of transport connections. The CoNet architecture should ensure that the interoperability of (and communication between) heterogeneous endpoints is maintained.

Security

The CoNet architecture should provide a securely protected environment in which network elements are deployed and interact. Besides protecting end users and networks from each other through authentication and authorization, the components of the CoNet concept should also be protected from any intrusion or malicious attack. The architecture should provide a security framework to enable protection of private information and data. Furthermore, the CoNet architecture should provide accounting capabilities and further enhance the AAA paradigm. The architecture should be distributed and consist of security components able to communicate through well defined interfaces. Underlying mechanisms such as DIAMETER [3] would provide the necessary secure communication framework where multiple networks cooperate. To accomplish these, we would be well advised to rely on already existing security algorithms that are stable, resilient, and well established.
The creation of new mechanisms and protocols is outside the scope of CoNet. Rather its objective is to build the trust models and security associations between the various

components of the distributed CoNet architecture with scalable access control to distributed components and resources.

Self Organizing CoNets

The CoNet architecture is expected to comprise a number of networks exhibiting different capabilities in terms of coverage, capacity, transmission rates, transmission delay, and transmission cost. Networks might be in a cooperative or competitive relationship with each another. Part of the access domain in the wireless world may not be centrally organized in the future and may even provide infrastructureless connectivity. Nodes may come and go and be loosely associated with each other, forming alliances whenever and wherever. Such nodes that could be part of the personal, the local, and even the global sphere would temporarily cooperate to provide connectivity in an ad hoc manner or share application resources. A network
that is a member of the CoNet has to build relations
with other networks to provide expected global connectivity and support the demanded access versatility. Relations between cooperative networks are supposed to be established dynamically. The creation of these dynamic relationships is a first aspect of self-organization. The dynamic organization of relations
between networks and individual network elements is supposed to result in a CoNet structure that adapts its topology to meet the demands of varying traffic patterns and transmission demands. To ease administration and operation, the network nodes should mostly be self-configuring, and resources should be distributed among
them dynamically to cope with varying traffic
volumes and traffic characteristics.

Cooperative Services

The services provided in 4G will depend on time, place, terminal and user.

$$S_{4G} \sim f(time,\ place,\ terminal,\ user)$$

Cooperative service support by customer diversity

We assume a certain number of *Wireless Stations* (WSs) in the range of the same *Base Station* (BS), served by the same multicast service flow. In case only one terminal out of the group has received the overall information, the needed retransmissions are performed locally.

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The terminals in the same multicast group are in physical proximity, such that they can communicate with each other using high-speed wireless links. Due to the multi-user diversity, there is a high probability that at least one of them will receive the downlink multicast packet correctly; that terminal may hence become leader – *Cluster Head* (CH) – and take the responsibility, if needed, to retransmit the data packet locally by using links with high data rate. In addition, it should also acknowledge the reception of the downlink packet towards the BS. Contrarily to ad-hoc networks where the scope is to achieve a better routing and the retransmissions are performed at the IP.

Local retransmissions within the same short-range group
have the following advantages:
• Retransmitted packets from neighboring terminals will be transmitted at a lower power level than it would be done by the BS, thus leading to a lower interference for parallel ongoing communications.
• Retransmissions can be performed by exploiting the unlicensed band, thus providing the service at a lower price.
• The BS can reserve some licensed band for the retransmissions in each group.

$$\boldsymbol{R = f(1/GS)}$$

where *R* and *GS* are respectively the amount of retransmissions and the group size. This allows an adaptive regulation of redundancy in dependency of the group size.

Increasing the quality of service due to customer accumulation

We assume a finite number of terminals in the range of the same BS served by the same video flow – as an example, we suppose a video streaming encoded by using the *Multiple Description Coding* (MDC). In order to increase the quality of the video, we propose that the BS transmits disjunctive descriptors to the different members of the group. Therefore, even if the higher data rate cannot be processed by one terminal alone over the cellular air interface, different terminals will receive different descriptors and repeat/forward them over the short-range air interface, thus having more bandwidth available. As a consequence, the increasing QoS will be dependant on the number of users belonging to the same group:

$$\boldsymbol{QoS = f(GS)/\ (2)}$$

where *GS* is the group size.

The proposed service infrastructure hence induces the users to form cooperative groups in order to achieve the common benefit of an enhanced quality of service.

Perspective of 4G in European Market

It outlines two divergent visions on 4G: the so-called“immediate” 4G vision, consisting of wireless local area networks (WLANs) combined with other wireless access technologies, competing with 3G in the short term, and the so-called “linear” 4G vision, in which the 3G standard is not
replaced until the end of its life cycle by an ultra-high speed broadband wireless network. Which of these visions will materialise, and what this means for the competitiveness of the main 4G stakeholders in Europe, will be to a large extent determined by which business models are feasible for 4G.

Conclusion

The aim of this research review was to explore the advents in the field of cooperative networks being particularly deployed for 4G. The report overviews divergent definitions of 4G. It lists out key features of 4G technology and also looks at challenges in deployment of 4G. what makes 4G interesting is that it is not confined to basic mobile device or services. 4G has capability to facilitate emergence of new businesses which will provide content for the services which 4G proposes. They will be rightfully known as content providers. Interesting challenge for future research can be how far cooperative networks can tackle the challenges faced by 4G and emerge as an universal architecture for next generation devices.

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