# NOUA GENERAȚIE DE FEMTOCELULE ȘI SISTEMUL 5G

# NEXT GENERATION OF FEMTOCELLS AND 5G SYSTEM

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***Cuvinte cheie.*** *Sistem, comunicații, femtocelule, tehnologie, rețea, aplicații, servicii.*
***Rezumat.*** *Scopul acestui articol este de a prezenta rolul femtocelulelor în cadrul sistemelor de comunicații mobile de ultimă generație. În acest articol se realizează o comparație între tehnologiile 4G și 5G. De asemenea, se precizează caracteristicile tehnologiei 5G și aplicațiile care vor fi oferite. Noua generație de femtocelule are un rol foarte important în prevederea de servicii multimedia avansate în diverse scenarii ce acoperă mediul de interior aflat la domiciliu și mediul mobil de exterior precum și în asigurarea suportului multimedia pentru serviciile de urgență și siguranță. Noua generație de femtocelule contribuie la creșterea capacității totale a sistemului prin mărirea acoperirii rețelei.*

***Keywords.*** *System, communications, femtocells, technology, network, applications, services.*
***Abstract:*** *This paper is presenting the femtocells employment within the next generation mobile communications systems. A 4G versus 5G technologies and applications short review is accomplished in order to demonstrate the femtocells convenience within broadband networks. The emerging femtocells are intended to support innovative multimedia services and emergency and safety services for different coverage and mobility scenarios, for both indoor and outdoor environment. The next generation femtocells are aiming to increase both the total system capacity and the network coverage.*

## 1. Introduction

The 4G wireless mobile all-IP technologies, including LTE-Advanced, WMAN-Advanced (or WiMax 2), and HSPA+, are able to deliver 100 Mbps peak speed services for high mobility communications and 1000 Mbps peak speed services for low mobility communications [1]. The 4G services, to name IP telephony, gaming, mobile HDTV, video conferencing, 3D TV and mobile web access, are enabled by wider bandwidths and higher bit rates than that of the 3G predecessor.

The ramp-up to 5G network system is aiming to provide much higher speed (up to 1 Gbps) and capacity, lower latency, and lower cost per bit for IP-based services than today's wireless cellular systems do. The 5G system should grant any user, anytime and anywhere, an infinite access to data.

From a user point of view, the 5G system will improve existing properties and develop new qualities of the wireless systems [2]:

- Increased maximum throughput;
- Lower battery consumption;
- Better coverage and high data rates available at cell edge;

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- Multiple concurrent data transfer paths;
- Around 1 Gbps data rate in mobility;
- Improved cognitive radio (CR)/software defined radio (SDR) security;
- Worldwide wireless web (WWWW), wireless based web applications that include multimedia capability at faster speeds than 4G;
- More applications combined with artificial intelligence (AI);
- Low infrastructure deployment costs involving cheaper traffic fees.

Table 1 shows out a comparison between 4G technology and the future 5G technology [3], [4].

**Table 1. Comparison between 4G and 5G technologies**

| ***Technology/Features*** | ***4G*** | ***5G*** |
|---|---|---|
| **Data bandwith** | 2Mbit/s to 1Gbit/s | 1Gbit/s and higher |
| **Standards** | Single unified standard | Single unified standard |
| **Technology** | Unified IP and seamless combination of broadband, LAN/WAN/PAN and WLAN | Unified IP and seamless combination of broadband, LAN/WAN/PAN and WLAN and WWWW |
| **Services** | Provides dynamic information access, wearable devices | Provides dynamic information access, wearable devices with AI capabilities |
| **Applications** | Provides high definition streaming and some additional features such as multimedia newspaper and ultrabroadband Internet access | Includes large phone memory, dialling speed and much more. We can connect 5G cell phones with laptop to have broadband Internet access. |
| **Bandwidth per frequency channel** | Up to 100 MHz | Up to 28 GHz |
| **Detection or avoid of the error** | Are used concatenated codes for error detection | The high quality of service based on policy to avoid error |
| **Multiple access** | CDMA | CDMA and BDMA |
| **Core network** | Internet | Internet |
| **Handoff** | Horizontal and vertical | Horizontal and vertical |

The mobile communication system must provide good quality services to a large number of users and at lower cost. A big problem for wireless technologies is to increase system capacity and quality with the use of a limited frequency spectrum. For solving this problem are used multiple access techniques like FDMA, TDMA, CDMA and OFDM. On the other hand the capacity of a mobile communication system depends on time and frequency. But for 5G system the Korean research and development propose BDMA (Beam Division Multiple Access) as radio interface. In this technique the base station allocates separate beam to each mobile station for that it divides the antenna beam according to the location of mobile stations. This technique significantly increases system capacity.

Among the main features of 5G system we can mention [1]:

- Provides high resolution and bidirectional huge bandwidth;
- Ensures high connectivity speed with less traffic;

- ❖ Supports high uploading and downloading speed up to 1Gbit/s;
- ❖ Supports virtual private networks (VPN).

From the main applications of 5G system we can specify mobile telephony and mobile broadband and media delivery. However there are some applications related to end to end communication between devices, known as machine-type communication (MTC). 5G system can provide wireless connectivity for a wide range of applications like smart homes, traffic protection and control, critical infrastructure and industry applications and for very high speed data delivery. We can say that 5G system represent a general solution for the necessities of mobile communication around the year 2020.

On the other hand the 5G system will have exceptional applications with common features as [5]:

- ✓ One can know weather, temperature and location etc. of each other when the conversation is made;
- ✓ One can complete the work without going to the office;
- ✓ One can locate his/her child when she/he is missed;
- ✓ Students can attend the classes of any institute of the world without going there;
- ✓ Doctors can treat patients of other countries;
- ✓ The possibility to monitor any place of the world from anywhere.

5G will be a new technology that will offer all the possible applications, by using only one universal device and interconnecting most of the existing communications infrastructure. The 5G networks will be based on the development of user terminals. These terminals will be able to access different wireless technologies at the same time.

The technology used for 5G network will have features like [5]:

- ⇨ The files (even movies) can be downloaded within seconds;
- ⇨ The pages will be uploaded almost instantly;
- ⇨ We can play easily online games;
- ⇨ The 5G devices will be less expensive than 3G and 4G devices;
- ⇨ Easily support previous generations;
- ⇨ No limitation as user demands;
- ⇨ Possibility to support new services;
- ⇨ The best Quality of Services (QoS);
- ⇨ Subscribers will be able to store data in central storage;
- ⇨ Remote PCs can be controlled by handsets;
- ⇨ The security will be distributed on several layers;
- ⇨ The high QoS for 5G technology will be based on policy to avoid error.

**Concept of Femtocells**

Femtocell is known as „home base station". Furthermore femtocells are cellular network access points that connect standard mobile devices to a mobile operator's network through residential DSL, cable broadband connections, optical fibres or wireless last-mile technologies. The femtocell unit includes the functionality of a typical base station, like Node-B in UMTS. As we can see in figure 2, a femtocell unit looks like a Wi-Fi access point but it contains Radio Network Controller (RNC) and all the core network elements [6].

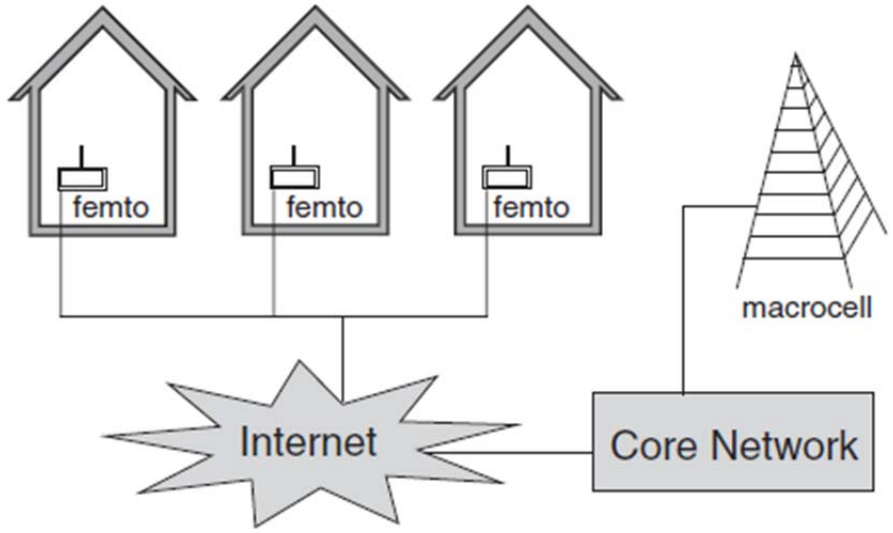


**Figure 2. A typicall femtocell and macrocell scenario [6]**

A femtocell unit does not require a cellular core network but requires only a data connection to Internet (through DSL, cable etc.) and through this is connected to the mobile operator's core network. Ussually femtocells cover a smaller area (only one house) and have fewer users than picolless. Furthermore they have to be cheap and are limited in output power and capacity (between 10 and 20dBm and for 3 – 5 users). The figure 3 illustrates the way in which the cell sizes evolved over time. We can see that the cell sizes was reduced to meet the networks requirements for which de capacity demand is increasingly higher.

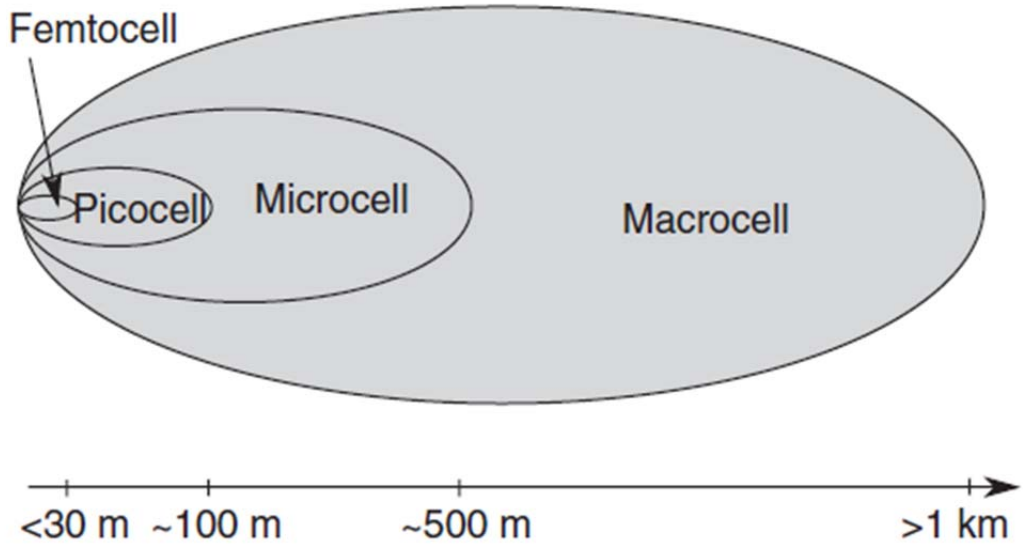


**Figure 3. The evolution of cell sizes [6]**

Among the femtocells advantages we can mention:

- ✶ Good coverage for subscribers;
- ✶ Better voice quality and higher data rates for subscriber;
- ✶ Increase of the indoor coverage for operators;
- ✶ The femtocells represent a cheap solution for operators (because femtocells are paid by the customers)

Table 2 presents a comparison between picocells and femtocells. It can be seen that femtocells are small picocells for which the properties have been simplified and thus the cost is reduced and the installation is simplified [6].

**Table 2. Comparison between picocells and femtocells [6]**

| ***Parameter*** | ***Picocells*** | ***Femtocells*** |
|---|---|---|
| Installation | By the operator | By the user |
| Capacity | 10-50 users | 3-5 users |
| Covering range | <100m | <30m |
| Price | Cheap | Very cheap |

It can be said that femtocells are very important for the following reasons:

- → It can ensure indoor coverage for places where macrocells can not achieved this coverage;
- → The addition of a femtocells layer significantly improves the total network capacity by reusing radio spectrum indoors (assume that a good isolation can be achieved);
- → Femtocells provide an ideal solution for Fixed Mobile Convergence (FMC);
- → Femtocells play a significant role in mobile broadband and ubiquitous communications.

The architecture of 5G network is heterogeneous with macrocells, microcells, femtocells and relays. Because there are high-mobility users like users in vehicles and high-speed trains it can considered the mobile femtocell concept which combines the concepts of mobile relay and femtocell. These mobile femtocells are located inside vehicles to communicate with users within the vehicle and large antenna equipments are located outside the vehicle for comunications with outdoor base stations (BS). An mobile femtocell and its associated users can be considered as a single unit to the BS. Figure 4 illustrates a 5G heterogeneous cellular architecture. An mobile femtocell represents a small cell that can move around and dynamically change its connection to a core network of the operator. The mobile femtocells using are very important because [7]:

- It can improve the spectral efficiency of the network;
- It can contribute to signalling overhead reduction of the network (the mobile femtocell can achieve a handover for all its associated users, which can reduce the handover activities for users within the mobile femtocell);
- It can be reduced the energy consumption of users inside a mobile femtocell (due to relatively shorter communication range and low signalling overhead).

For 5G architecture design we can separate outdoor and indoor scenarious such that the penetration loss through building walls are somehow avoided. This may be associated with the use of distributed antenna system (DAS) and of massive multiple input, multiple output (MIMO) technology.

A large portion of the radio spectrum is underutilized in the most of the time and this is the reason for using cognitiv radio technique. This techique is one way to improve the utilization of the congested radio frequency (RF) spectrum. In CR networks, a secondary system can share spectrum bands with the licensed primary system, on an interference free basis or on an interference tolerant basis [7].

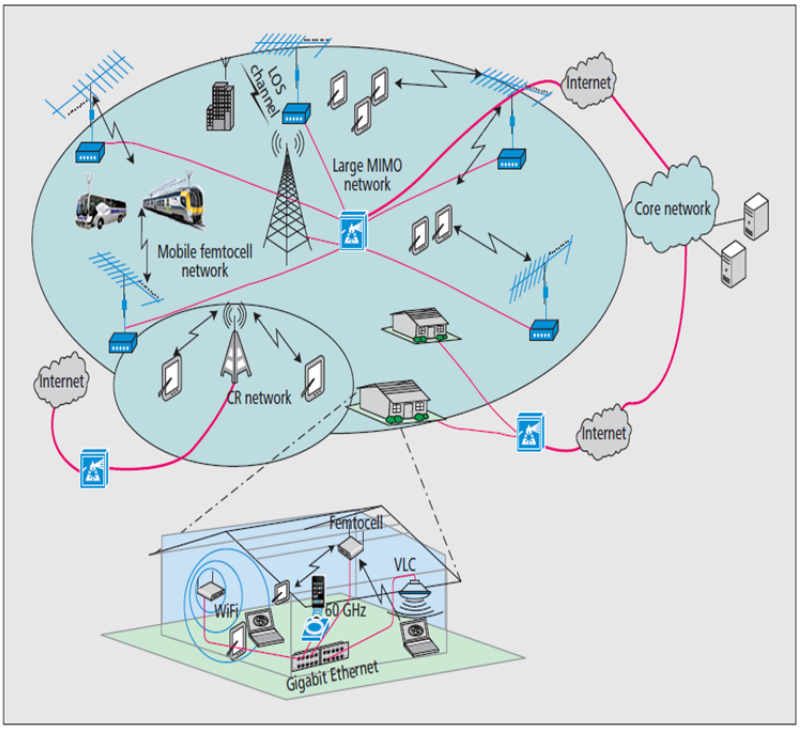


**Figure 4. A 5G heterogeneous cellular architecture [7]**

One of the main purposes of 5G networks is to enable an important capacity increase with efficient utilization of all possible resources. Based on Shannon theory, the total system capacity (expressed through $C_{sum}$) can be calculated with the following formula [7]:

$$C_{sum} \approx \sum_{HetNets} \sum_{Channels} B_i \log_2 \left(1 + \frac{P_i}{N_p}\right)$$

where:
$B_i$ represents the bandwidth of the ith channel,

$P_i$ represents the signal power of the ith channel,

$N_p$ is the noise power.

We can increase $C_{sum}$ through increasing:

- The network coverage (through heterogeneous networks with macrocells, microcells, picocells, relays, mobile femtocells etc.);
- The number of subchannels (through masive MIMO, spatial modulation, cooperative MIMO, DAS etc);
- The bandwidth (through CR networks, millimeters-wave communications (30-300 GHz), visible light communications (VLC) (400-490 THz) etc);
- The signal power (through energy-efficient or green communications).

Besides this, the next generation of femtocells has a very important role in provision of advanced multimedia services in different scenarious covering the indoor home environment and outdoor mobile environment, as well as in providing multimedia support for emergency and safety services [8].

**Conclusions**

5G represents ***the next step in evolution of mobile communication system after 4G*** and is designed to ***ensure high speed, high capacity, low cost per bit and IP based services.***

Among the main features of 5G system we can mention: provides high resolution and bidirectional huge bandwidth, ensures high connectivity speed with less traffic, and supports high uploading and downloading speed up to 1Gbit/s.

Femtocell is known as ***„home base station"***. Furthermore femtocells are cellular network access points that connect standard mobile devices to a mobile operator's network through residential DSL, cable broadband connections, optical fibres or wireless last-mile technologies.

The architecture of 5G network is ***heterogeneous with macrocells, microcells, femtocells and relays***. The ***mobile femtocell concept*** combines the concepts of ***mobile relay and femtocell***. These mobile femtocells are located inside vehicles to communicate with users within the vehicle and large antenna equipments are located outside the vehicle for comunications with outdoor BSs. An mobile femtocell and its associated users can be ***considered as a single unit to the BS***. An mobile femtocell represents a small cell that can move around and dynamically change its connection to a core network of the operator. The mobile femtocells using are very important because:

- It can ***improve the spectral efficiency*** of the network;
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In general, it can be said that femtocells ***are very important*** for the following reasons:

→ It ***can ensure indoor coverage*** for places where macrocells can not achieved this coverage;
→ The addition of a femtocells layer significantly ***improves the total network capacity by reusing radio spectrum indoors***;
→ Femtocells provide **an ideal solution for Fixed Mobile Convergence** (FMC);
→ Femtocells play ***a significant role in mobile broadband and ubiquitous communications***.

**Acronyms used in paper**

| Acronym | Signification |
|---|---|
| 3G | 3rd Generation |
| 4G | 4th Generation |
| 5G | 5th Generation |
| 6G | 6th Generation |
| 7G | 7th Generation |
| AI | Artificial Intelligence |
| BDMA | Beam Division Multiple Access |
| BS | Base Station |
| CDMA | Code Division Multiple Access |
| CR | Cognitive Radio |
| DAS | Distributed Antenna System |
| DSL | Digital Subscriber Line |
| FDMA | Frequency Division Multiple Access |
| FMC | Fixed Mobile Convergence |
| HSPA | High Speed Packet Access |
| IP | Internet Protocol |
| LAN | Local Area Network |
| LOS | Ligne Of Sight |
| LTE | Long Term Evolution |
| MIMO | Multiple Input, Multiple Output |
| MTC | Machine-Type Communication |
| OFDM | Orthogonal Frequency Division Multiplexing |
| PAN | Personal Area Network |
| PC | Personal Computer |
| QoS | Quality of Service |
| RF | Radio Frequency |
| RNC | Radio Network Controller |
| SDR | Software Defined Radio |
| TDMA | Time Division Multiple Access |
| UMTS | Universal Mobile Telecommunications System |
| VLC | Visible Light Communications |
| VPN | Virtual Private Network |
| WAN | Wide Area Network |
| Wi-Fi | Wireless Fidelity |
| WiMax | Worldwide Interoperability for Microwave Access |
| WLAN | Wireless Local Area Network |
| WMAN | Wireless Metropolitan Area Network |
| WWWW | WorldWide Wireless Web |

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