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NLM FOR IMPROVEMENT OF SENSING CAPABILITY IN FEMTOCELLS

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Abstract: This paper presents the working of Network Listen Module (NLM) which is used to improve the sensing capability of Femtocell device. Using NLM, the Femtocell will be able to scan the air interface, detect neighboring cells and tune its network and RF parameters accordingly.

Keywords: NLM, Femtocell, DTX, STX, RSSI

1. INTRODUCTION

Femtocells are 'domestic base stations' which acts like cellular network access points used to connect mobile devices to mobile network service providers using residential DSL, cable broadband connections, optical fibers or wireless last mile technology.

It is a low power base station communicating in a licensed spectrum, offering improved indoor coverage with increased performance, improved voice and broadband services in low cost with the operators approval.

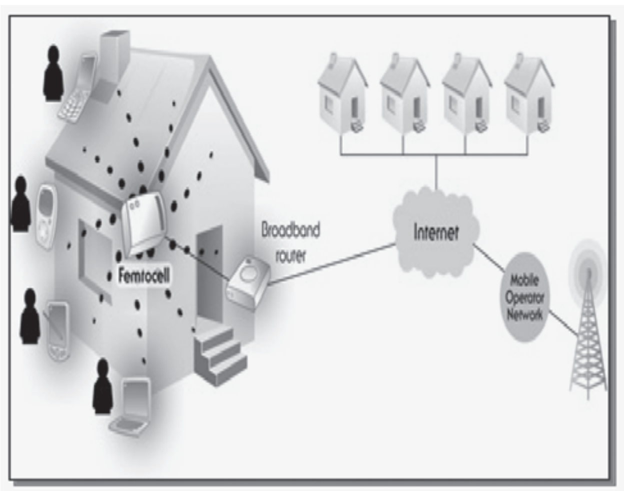

Figure 1. Femtocell house

A femtocell looks like a WiFi access point which contains RNC (Radio Network Controller) and all the core network elements. It requires a data connection to the DSL or cable to the Internet, through which it is connected to the mobiles operator core network. The femtocell works through cellular network provider and enhances connectivity for cellular phones, smart phones and other portable/mobile devices especially in thelocations where coverage by cellular systems using large cells is weak and discontinuous. Finally, the mobile devices are connected to the backbone of the network supplied by Internet service provider via femtocells.

2. NETWORK LISTEN MODULE

When a customer buys a femtocell, the network operator provides the customer with the femtocell device and a femtocell ID. This femtocell ID will be used to register and authenticate the femtocell in the network after switching on. Moreover, when the customer buys the femtocell, he/she must provide some information to the operator. For example, the address where the femtocell is going to be installed and the list of femtocell subscribers (registration data). Furthermore, in order to let the customer update the list of subscribers, the operator also gives him/her a secure web site. It is to be noted that, the list of authorized users resides in the core network.

After acquiring the femtocell, the customer only needs to plug the femtocell into a power source and Internet connection to start using it. The customer cannot be assumed to have the knowledge to install or configure the femtocell, hence these processes need to be automatic. Therefore, after power on, the first thing the femtocell does is to connect to the network of the operator through the backhaul connection.

The femtocell is then authenticated and registered into the system as an operative device by the OSS, using the femtocell ID. Afterwards, the femtocell can update its software by downloading the latest available version from the OSS. Note that this software update can also be triggered by the OSS at any time after power on. Subsequently, the femtocell verifies the functioning of this new software, self-testing the installation.

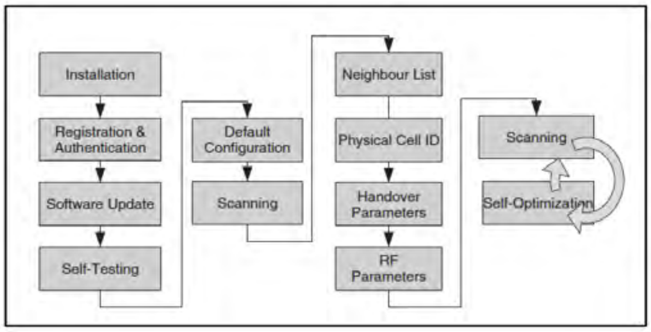

Figure 2. Femtocell start up procedure

Fundamental information such as:

- frequency for DL and UL,
- scrambling code list, or
- radio channel bandwidth

  must be provided during the booting procedure by the operator over the backhaul link.

Network configuration parameters:

- location, routing and service area code information,
- neighbouring list,
- physical cell ID,
- RF parameters (pilot and maximum data power . . .)

  can be automatically calculated from information on the macro cell layer provided by the operator (OSS data), and from information on the femtocell layer provided. By the users (registration data). These data arrive at the femtocell through the backhaul link.

If the core network does not support this configuration or cannot supply any suggestions, the femtocell will derive these parameters, using data gathered by monitoring the radio channel. However, setting up the femtocell parameters from a blind configuration using only sensing techniques will delay the booting procedure, and might result in an undesirable performance. Therefore, it is advisable that a default configuration is provided by the femtocell firmware or through the backhaul.

The sensing of the radio environment is done by the network listening mode, designed to scan the air interface. By decoding the existing broadcast and control channels, the femtocell synchronizes its internal oscillator and synchronizes the femtocell to the external network. The information derived from the initial sensing is also used to detect new neighbouring macrocells and femtocells. In this way, the default configuration of the femtocell can be set up or reconfigured [22]. For example, the femtocell can add or remove new neighbouring relationships, select/re-select its physical cell ID in order to minimize the collision probability, or tune its handover parameters in order to facilitate the handover procedure towards other cells.

After the femtocell has been self-configured, the life cycle of a femtocell moves towards a self-optimization loop, since the femtocell needs dynamically to adapt its parameters to the changing environment conditions.

Using the network listening mode and other inputs, e.g. broadcast messages, measurement reports, cognitive radio the femtocell will collect statistics to optimize its performance dynamically (coverage and capacity). For example, in order to provide an adequate signal quality to its users, and minimize the impact (interference) on other cells, the femtocell will adapt its power and channel usage, as well as optimizing its neighboring list and handover parameters according to the gathered information.

The most challenging environment is that of the home because the femtocell base station must be installable by the home owner and the femtocell must be able to zero touch self configuration to allow the femtocell to interoperate with the existing Radio Access Network while causing the minimum interference to the existing infrastructure.

From a network operators perspective the main requirements for the femtocell is to fit into the network with the minimum level of operator involvement in the process while minimizing the impact of the femtocell on the existing network. In order to do this the femtocell is required to boot up into a UE / network listen mode so that it can scan the air interface for available frequencies, scrambling codes and other network resources.

A further complication for femtocell deployments is that they are typically connected to the operators network through an IP connection and further they are located in doors so the femtocell does not have access to any of the usual facilities for providing timing and synchronization - for example the ATM backhaul or GPS 1pps signal. The timing and frequency synchronization requirements for modern radio networks are very tight (typically 0.1 ppm) and while there are network timing protocols such as NTP or IEEE1588 available, these often struggle to achieve the required accuracy.

In addition to the requirements of being a zero touch solution from both the operator’s and the user’s perspective and having to minimize the interference with the macro network and other mtocells; the femtocell also has to provide seamless hand-in and hand-out to the macro network.

2.1. Network Detection and Integration

During boot up it is imperative that the femtocell correctly detects the surrounding network and integrates into it with the minimum interference. The startup procedure for a femtocell can be summarized by the following four stages:

- Synchronizing the internal oscillator of the femtocell and synchronize the femtocell to the System Frame Number (SFN) of the external network.
- Search the surrounding radio environment (including 2G and 3G macro networks) for neighboring macro and femto cells. The search process detects the frequencies used, scrambling codes, CPICH Receive Signal Code Power (RSCP) and UTRA Receive Signal Strength Indicator (RSSI) required to minimize network interference and optimize the transmit power.
- Decode the neighbor cell information to configure a handout neighbor list and update the system database.
- Establishing the country code and location to ensure the device is being used within the terms of the operator's license.

In a UMTS network the cell search process must detect the following information from the network:

1. P-SCH: slot sync
2. S-SCH: frame sync + SCG identification
3. P-CPICH I : PSC identification

Note stage 2 can be avoided in a warm search mode to significantly reduce the amount of time required to perform the search - for example when the femtocell is already aware of the Primary Synchronization Codes (PSC) in use on the network.

2.2. Decoding The Synchronization Channel (SCH)

A UMTS network broadcasts the cell and system information on the Broadcast Channel (BCH). This information is required by the femtocell before it can be integrated into the network. The Synchronization Channel (SCH) is transmitted by the base stations and used by the UEs for cell search. There are actually two sub-channels on the SCH the Primary (P-SCH) and Secondary (S-SCH), each with a 10 ms frame length. The 10 ms frames are divided into 15 slots, each of length 2560 chips. This information is used in a five stage cell search process, as follows:

- Search for the P-SCH and output the slot header information
- Using the slot header information, S-SCH decode gives the frame header and scrambling code group information
- The scrambling code group information allows the detection of the primary scrambling code number
- Calculate the frequency offset of the base station by using the primary scrambling code number from 3
- Measure the Received Signal Code Power (RSCP) of the base station by using the primary scrambling code number from 3.

2.3. Timing And Synchronization

The femtocell is required to detect the time and frequency from the radio network because it is not always possible to be able to achieve this over the network interface. In order to be able to achieve these timing requirements it is necessary to use a very accurate crystal oscillator that is typically voltage and temperature controlled and housed in an oven to control the temperature Crystal oscillators that meet these requirements are typically much too expensive to be used in a consumer product so it is common to use cheaper crystals thatneed to be re-conditioned on a regular basis.

The internal clock is responsible for:

- The accuracy of the absolute timing to ensure frame alignment between receiver and transmitter and to avoid Intersymbol Interference (ISI)
- The spectrum accuracy to maintain frequency alignment between the receiver and the emitter.

Clock Accuracy Requirements

The accuracy of a clock is usually measured in parts-per-billion (ppb) or parts-per million (ppm). These units represent the maximum variation obtained over a high number of oscillations. For example a watch crystal has a typical error of 20 ppm, giving a maximum error per day equal to $0.00002 \times 24 \times 60 \times 60 = 1.7$ seconds.

In the 3GPP specifications, the requirements defined for a NodeB ask for a precision of 50 ppb. However in Release 6 it has been relaxed to 100 ppb for indoor base stations, and later in Release 8 is reduced to 200 ppb for Home nodeB with certain standards. Some typical accuracy requirements for femtocells recommended by 3GPP are summarized in Table 9.1. Even if it is reasonable for macrocell base stations to afford expensive and accurate oscillators, this is not the case for FAP, which need to be manufactured at low prices. Therefore cheap and easily implementable solutions are still required in this field.

3. OSCILLATORS FOR FEMTOCELLS

Piezoelectricity is the ability of certain materials (like quartz) to create an oscillating electrical potential when mechanical pressure is applied. The resonance of this material can be used to create a signal oscillating at an accurate frequency. Cheap crystals usually have a precision of about 20 ppm. However, the main drawback of such material is that the oscillation frequency changes with the temperature. Furthermore these changes do not repeat exactly upon temperature variation, i.e. resonators exhibit an hysteresis in the frequency variation. That is why in femtocells some more advanced oscillators must be used, in order to compensate for the errors due to the variations in temperature.

3.1 Temperature Controlled Crystal Oscillators

A Temperature Controlled Crystal Oscillator (TCXO) is a type of oscillator that compensates for temperature changes to improve stability. In a TCXO, the signal from a temperature sensor is used to generate a correction voltage that is applied to a voltage-variable reactance, also called varactor. The varactor then produces a frequency change equal and opposite to the frequency change produced by temperature.

TCXOs are used in many applications, which is why they are the cheapest accurate oscillator components. Because when using a TCXO there are always delays between the measurement of the temperature change and the generation of the frequency correction, the compensated frequency is not perfectly stable.

4. SYNCHRONIZATION VIA SENSING OF THE NETWORK

To avoid using the backbone connection as a reference, a good approach could be to listen to neighboring cells, in particular the surrounding macro cell. Indeed, the condition for low price is not requested by the macro cells, which is why they are equipped with accurate oscillators, and also very often with GPS receivers to synchronize them. This is why the timing accuracy is high in macro cells, and an efficient synchronization solution would be for the FAP to listen to the nearest macro cell to synchronize its clock. If the clock is not accurately synchronized it is possible that a subscriber, who enters his home, will not be able to handover from one cell to another. Moreover, if the frequency shift of the femtocell is too high, it could happen that the mobile would not be able to decode the different channels of the femtocell.

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Dr S.Srinivasa Rao received his B.Tech degree in Electronics & Comunication Engineering from Anna University, M.Tech from JNTU Hyderabad and PhD from JNTU Hyderabad. He has more than 23 years of teaching experience and published more than 20 research papers in reputed National & International Journals and conferences. He is Professor & Head in Department of Electronics Communication Engineering, Malla Reddy college of Engineering & Technology, Hyderabad. His areas of interest are Wireless Communications, Mobile Communications & Adhoc Networks.