Real-Time Collection of Electromagnetic Field Measurements using a Metropolitan Wireless Mesh Network[1]

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Abstract

We present a system for real-time collection of Electromagnetic Field (EMF) measurements. The two innovative features of the system that differentiate it from other similar monitoring systems are the use of a low-cost EMF measurement device and the collection and access of measurements through a metropolitan wireless mesh network. The low-cost EMF measurement device is connected to a mini-ITX based PC, and both are located in a water-proof enclosure. The EMF monitoring node is connected to a metropolitan wireless mesh network, which we have deployed in the city of Heraklion, Crete. A set of software module are responsible for collecting, processing, and presenting the EMF measurements in the form of graphs that are accessible from a web browser. The software modules support per-band, per-operator, and time-series monitoring, in addition to on-demand monitoring of a specific frequency range and time interval.

1. Introduction

The rapid growth of wireless technology has brought to the forefront of public interest and concern the issue of increasing electromagnetic field (EMF) radiation. All electrical devices release EMF radiation in a variety of frequencies, and with different transmitted powers. In this paper we present an innovative system for the collection, processing, and presentation of EMF measurements. The system consists of an EMF monitor node connected to a metropolitan wireless mesh network, and a set of software modules for collecting, processing, and presenting the EMF measurements in a variety of formats. The monitoring node contains a low-cost EMF measurement device that is connected to a mini PC, based on a mini-ITX board. The monitoring node is connected to a metropolitan wireless mesh network covering an area of approximately 60 Km^2 in the city of Heraklion, Crete [1]. The software modules allow the presentation of EMF measurements in different formats that include per-band, per-operator, time series, and on-demand measurements for a given frequency range and time interval. Two primary differences between the system presented in this paper, and other EMF monitoring systems, such as the one presented in [2], are the use of a low-cost EMF measurement device and the collection and access of measurements through a metropolitan wireless mesh network.

Monitoring of EMF radiation is becoming increasingly important, given the growing concern about electromagnetic radiation, especially from mobile telephony systems. Even though the exact implications of electromagnetic radiation on public health are not known, it is important to continuously monitor EMF levels and check conformance to national and international thresholds. Even when the assigned legal limits are not exceeded, the evolution of EMF levels can provide important information, which can be later used by the scientific community or public bodies and regulators.

The remainder of this paper is structured as follows: In Section 2 we present the design of the EMF monitoring node and the structure of the software modules for collecting, processing, and presenting EMF measurements. In Section 3 we present the EMF monitor node's interconnection with the experimental metropolitan wireless mesh network we have deployed in the city of Heraklion, and in Section 4 we present its ability to present EMF measurements in a variety of formats. We conclude the paper in Section 5, where we describe related ongoing activities.

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2. The Design of EMF monitoring node

The EMF monitoring node consists of the following parts: a low-cost EMF measurement device connected to an external antenna, a mini PC for controlling the EMF measurement device, and software modules for collecting, processing, and presenting the EMF measurements.

2.1 Electromagnetic Field Measurement device

The EMF measurement device is an Aaronia Spectran Analyzer, which is a low-cost spectrum analyzer. Our current system uses the HF 6060, which has a measurement range of 10 MHz to 6000 MHz. Additional monitoring nodes that we are currently deploying will use the HF 6080, which has a range of 10 MHz to 7000 MHz.

2.2 Antennas

The HF60X0 spectrum analyzer can be connected to two types of antennas: a directional antenna (HyperLOG 6080) and an omni-directional dipole antenna (BicoLOG 20300), Figure 1. The HyperLOG 6080 directional antenna has a range of 700 MHz to 7 GHz. The BicoLOG 20300 omni-directional dipole antenna has a range of 40 MHz to 3000 MHz. The BicoLOG antenna is more costly than the HyperLOG antenna, but can measure lower frequencies, which include the FM and TV bands. On the other hand, the lower cost HyperLOG directional antenna can measure higher frequencies, up to 7 GHz, but requires pointing it towards the area we are interested in measuring. Hence, the antennas present different tradeoffs. The currently deployed EMF monitoring node includes the omni-directional dipole antenna BicoLOG 20300.

Fig. 1.HyperLOG (left) and BicoLOG (right) antennas

2.3 Hardware

The EMF monitoring node contains a small PC, which is based on a mini-ITX board (EPIA SP 13000, 1.3 GHz C3, CPU) with 512 MB DDR400 memory, and an 80 GB 2.5" HDD. The EMF measurement device is connected to the mini-ITX through a USB cable. Figure 2 shows the component layout of the monitoring node. The hardware is placed in a water-proof enclosure, which has three external connections: a power supply, an Ethernet cable, and a cable for connecting the measurement device to the external antenna.

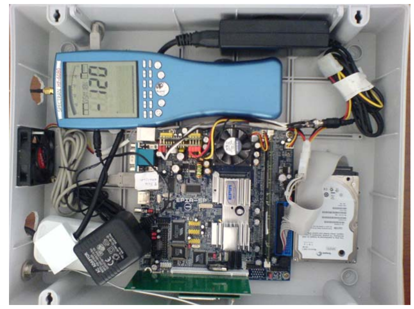

Fig. 2.Component layout of the EMF monitoring node

2.4 Software

The mini-ITX PC runs the Windows XP Pro operating system, since the Aaronia software for controlling and collecting measurements from the HF60X0 analyzer is available only for this operating system. To control the monitoring node remotely, we used the remote desktop application. The Aaronia software allows external configuration of the spectrum analyzer, for parameters that include frequency range, sample time, resolution bandwidth. The measurements (in dBm) taken from the HF60X0 analyzer are stored in a CSV (comma separated values) file. The data in the CSV file is processed by four Perl scripts, which are periodically executed every 5 minutes; this is performed using the Cron Tab software. The structure of the software modules is shown in Figure 3.

An apache server running on the mini-ITX allows remote access of the measurement graphs through a web interface. All four Perl scripts and the web server currently run on the monitoring node’s mini-ITX PC. This direction was followed, since we have currently deployed only one EMF monitoring node, and we wanted to test the capabilities of the mini-ITX PC. The forthcoming monitoring nodes being deployed will simply collect EMF measurements, which will subsequently be collected and processed at some central node; the latter can be either the currently deployed EMF node or a workstation connected to the fixed network.

The central workstation will also run the apache server to make the EMF measurement graphs accessible through a web browser.

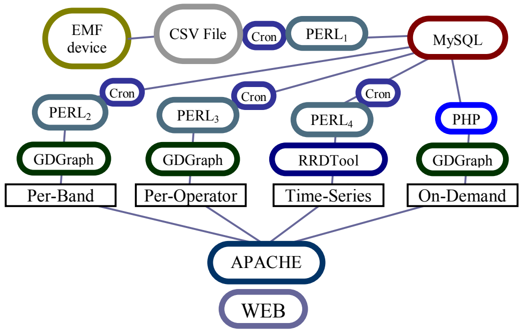

Fig.3.Structure of software modules

The first Perl script simply copies data from the CSV file, into a MySQL database. Additionally, the script removes the copied data from the CVS file, in order to limit its size. The other three Perl scripts are responsible for reading data from the database and for creating the graphs presenting the EMF measurements: per-band, per-operator, and time series. The per-band presentation shows the sum of the EMF levels for the various frequencies within a specific band, averaged over 6 minute intervals (6 minutes is the time interval indicated by Greece's National Telecommunications Committee, EETT [3]). The scripts use GD Graph, which is a tool for creating graphs with Perl and PHP. Per-operator graphs are the average EMF levels within the frequencies assigned to a specific mobile operator. Graphs are periodically updated, based on measurements within the last 6 minute interval.

In addition to the static (in time) per-band and per-operator graphs, the system can present EMF measurement as a function of time (time series). The RRD (Round Robin Database) tool is used for this purpose, since it enables daily, weekly, monthly, and yearly representation of measurements in each assigned band. Finally, there is an option for on-demand EMF measurements in a specific frequency range and time interval. The frequency range and time interval can be specified by a user through a web interface, and are later fed to a PHP scripts that create the corresponding graphs using the GD Graph tool.

3. EMF Monitoring Node and the Experimental Metropolitan Wireless MESH Network in Heraklion

Remote access to the EMF monitoring node is achieved through an experimental metropolitan wireless mesh network we have deployed in the city of Heraklion, Crete, which covers an area of approximately 60 Km^2. The mesh network currently contains 14 nodes, six of which are core multi-radio mesh nodes that are built from commodity components and contain up to four IEEE 802.11a (5 GHz) wireless interfaces [1]. The distance of the links between the core multi-radio mesh nodes ranges from 1 to 5 Km. The mesh network is connected to a fixed network through three nodes (FORTH - M1, FORTH - M2 and UoC – K4), Figure 4.[2]

Fig. 4 Heraklion Metropolitan Wireless Mesh Network

3.1 Interconnection of the EMF monitoring node and the Metropolitan Wireless Mesh Network

The EMF monitoring node was deployed at the location K5 + EMF shown in Figure 4. The monitoring node was installed next to a core multi-radio node, Figure 5, and connected to it using an Ethernet cable. The EMF monitoring node site was a rooftop opposite of a tower with many mobile telephony antennas, Figure 6. Our initial experience has shown that the EMF monitoring node design and its interconnection with the metropolitan wireless mesh network allowed smooth deployment without any serious problems, and the communication between core mesh node and the monitoring node is stable.

Fig. 5.Core mesh node (left) with EMF monitoring node (right)

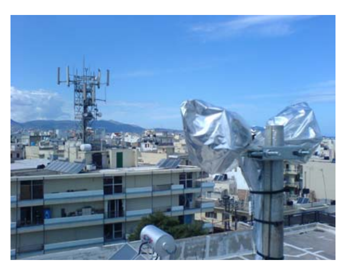

Fig. 6.The EMF node opposite of the antenna tower

[2] More information is available at http://ics.forth.gr/HMESH

3.2 Advantages

The advantages of using an EMF measurement device connected to a metropolitan mesh network for collecting EMF measurements include the following:

▪ Higher range: EMF measurement device can be used to monitor frequencies up to 7 GHz (with the appropriate antenna), which is higher than the capabilities from specialized stand-alone EMF monitors, whose range is typically limited to 3 GHz.

▪ Real-time remote measurement collection: EMF measurement devices with real-time monitoring capabilities together with a metropolitan coverage mesh network allow real-time remote collection of EMF measurement data.

▪ Low cost: Small (handheld) EMF measurement devices with advanced spectrum analyzer capabilities are significantly cheaper than standalone EMF monitoring devices with remote communication (GSM) capabilities.

▪ Advanced flexibility: Together with the mini PC, the EMF monitor can be controlled remotely to collect measurements in different frequency ranges (bands) and different time windows.

4. EMF Node monitoring capabilities

Next we discuss the monitoring capabilities of the EMF node. Since we used the BicoLOG omni-directional dipole antenna, the EMF node's measurement range was from 40 to 3000 MHz. The collected measurement data is in dBm units. In addition to the default units, the measurements can be presented in dBμV, mV/m, $\mu A/m^2$ and finally mW/m^2. We note here that electromagnetic radiation limits are usual represented in mV/m or mW/m^2. In the following subsections we describe the various types of measurements that are available through the web interface[3].

4.1. Per-Band Monitoring

This option allows the presentation of EMF levels in frequencies of various well-known bands. Table 1 shows the frequencies for each band. Figure 4 shows an example of per-band monitoring, where data is presented in dBm units. The displayed values are the average of measurements taken in time intervals of approximately 6 minutes. The graph is refreshed periodically, based on the last stored values in the database. Each bar corresponds to a different band. The bands shown in Figure 7, from left to right, are the following: FM, FM VHF, FM UHF, GSM 900 uplink and downlink, GSM 1800 uplink and downlink, 3G/UMTS TDD, FDD uplink, and FDD downlink, and finally IEEE 802.11 (WiFi). Note that the values for the GSM and 3G/UMTS bands are higher than approximately -80 dBm, which is due to the mobile telephony antennas located opposite of the EMF monitor node.

TABLE I
BAND FREQUENCIES

Bands	Frequencies			
FM	175 – 108			
TV	VHF		UHF	
	174 – 230		470 – 862	
GSM	900		1800	
	Uplink	Downlink	Uplink	Downlink
	880-915	930-960	1720-1785	1825-1880
UMTS	TDD	FDD Uplink		FDD Downlink
	1900 – 1920	1920 – 1980		2110 –2170
802.11	b/g		a	
	2400–2483.5		5150–5350	5470–5725

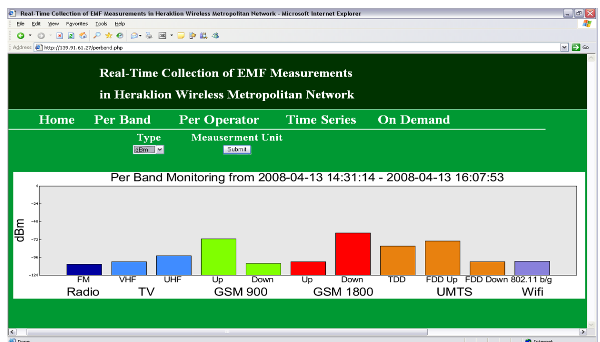

Fig. 7 Per-Band Monitoring

4.2. Per-Operator Monitoring

This option displays EMF levels of per-operator frequencies, according to the official frequency assignments made by the Greek government [3]. The EMF levels include measurements in all frequencies (GSM 900, GSM 1800, and 3G/UMTS).

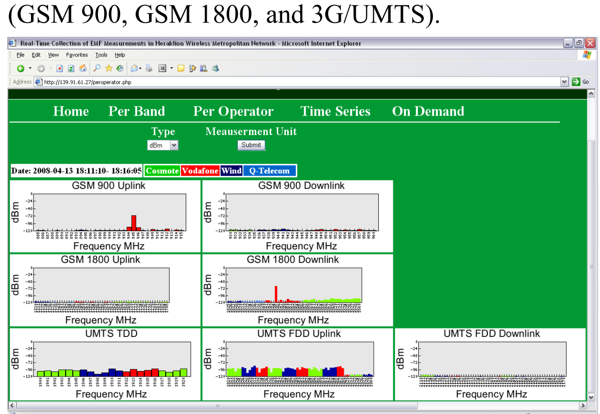

Fig. 8 Per-Operator Monitoring

[3] Real-time measurements are available at http://ics.forth.gr/emf

4.3. Time Series Measurements

The previous two monitoring options show the average of EMF measurements taken in the last 6 minute time intervals. Also important are the variations of measurement in a larger time-frame. To achieve this, we use the RRD (Round Robin Database) Tool, which allows the daily, weekly, monthly, and yearly presentation of measured values. A snapshot of the time series graphical display is shown in Figure 9. Additionally, the EMF values can be in units of mV/m (default), but also μA/m, dBm, and $\mu W/m^2$; the ability to display graphs in these units is also possible with the other monitoring options. Finally, we can use this monitoring option to compare the EMF levels in different bands, in the course of time. This will be especially important as the percentage of data, which is typically bursty in nature, carried over wireless networks increases.

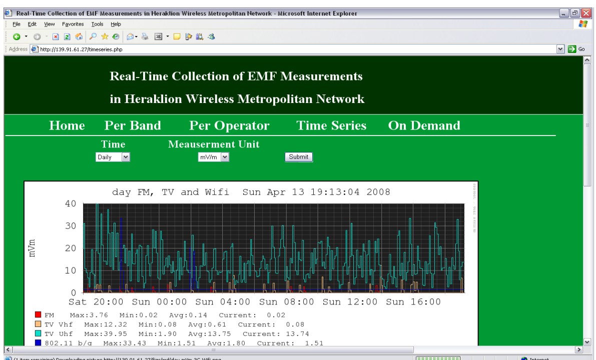

Fig. 9 Time Series Monitoring

4.4. On-Demand Measurements

The previous measurements were obtained automatically, for a fixed band or frequency range, and time interval. The software modules we have developed also allow on-demand measurements, where a user, through a web interface, selects the frequency and time interval range over which EMF measurements are to be obtained, and the unit in which the measurements are to be displayed.

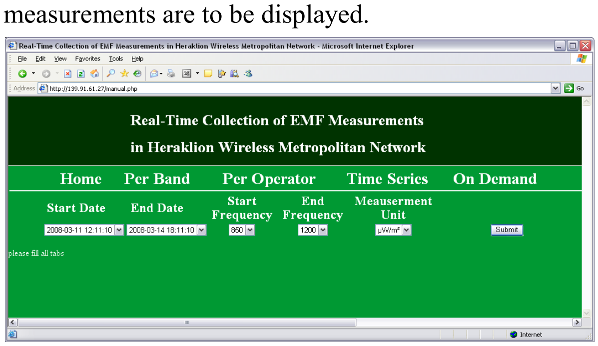

Fig. 10 On-Demand Measurements

5. Conclusion

We presented a system for real-time collection of EMF measurements. The two key innovations of the system are that it is based on a low-cost EMF measurement device, and measurements are collected and accessed using a metropolitan wireless mesh network that we have deployed in the city of Heraklion, Crete. A set of software modules are responsible for collecting, processing, and presenting the EMF measurements in the form of graphs of different types, which allow per-band, per-operator, time series, and on demand monitoring.

We are currently adding additional EMF monitoring nodes. Indeed, these nodes can connect to the metropolitan mesh network through a wireless 802.11a/g interface, rather than a wired Ethernet connection as in the case of the currently deployed EMF monitoring node that we discuss in this paper. Such an approach requires the addition of a wireless 802.11a/g client in each monitoring node, but allows greater flexibility in positioning the monitoring node, since we are no longer forced to locate the monitoring node next to a node of the metropolitan wireless mesh network. Moreover, such wireless EMF monitoring nodes will exploit to the fullest the coverage achieved by the experimental metropolitan wireless mesh network we have deployed in Heraklion. We are also investigating the use of batteries in conjunction with solar panels in order to avoid the requirement of a live power supply to the monitoring node. Another direction we are investigating is the collection and processing of the EMF measurement data in a central location, which can be either a monitoring node with enhanced functionality, such as the one presented in this paper, or a workstation connected to the fixed network.

6. References

[1] M.Delakis, K.Mathioudakis, N.Petroulakis, V.A.Siris, Experience and Investigations in Heraklion Mesh: An experimental multi-radio wireless mesh network. In Proc of 4th International Conference on Testbeds and Research Infrastructures for the Development of Networks & Communities (TRIDENTCOM), Innsbruck, Austria, March 2008.

[2] A. Gotsis et al, Non-ionizing electromagnetic radiation monitoring in Greece, Annals of Telecommunications, Vol. 63, No. 1-2, February 2008.

[3] Hellenic Telecommunications and Post Commission (EETT), National Regulatory Authority, http://www.eett.gr