

Femtocell Deployed Self Organizing Network for U-Health: Opportunities and Challenges

Anup Thapa and Seokjoo Shin[†]

Dept. of Computer Engineering, Chosun University, Gwangju, Republic of Korea

[†]Corresponding author: sjshin@chosun.ac.kr

Abstract—An initiative approach towards uniform integration of Wireless Body Area Network (WBAN) with various outgoing networks can provide a landmark in Ubiquitous Health care (U-Health) development. More interestingly, provided with Self Organizing Network (SON) characteristics, integration of WBAN with femtocell deployed cellular networks, which can bridge WBAN with widely deployed broadband connections as well, could alternatively be one of the simpler but pragmatic solutions for U-Health development. This paper highlights the opportunities of such an integrated network, analyzes both the technical and commercial challenges, and discusses some open issues.

I. INTRODUCTION

Wireless Body Area Network (WBAN) is a key technological breakthrough in health care. WBAN consisting of autonomous portable sensor nodes with intercommunicating radio interface is meant to monitor the patient's physiological parameters and feedback the updates to the physician or the authorized agents like family members, care givers, etc. via powerful external computing devices such as Personal Digital Assistant (PDA) or smart phones [1].

WBAN offers two main advantages over conventional health care [2]. First, it is cable-less, so that people are not confined in a small region any more. Second, multiple information can be collected autonomously by employing various sensor nodes without need of human intervention. Such new paradigm brings a number of unique advantages on health care [3],[4]. For instance, it can play considerable role on Ubiquitous Health care (U-Health), i.e. on sensing and monitoring of the patient's health round the clock and update the status to the physician or the authorized agents irrespective of the location.

U-Health has great potential on management of many diseases and conditions [5]. Monitoring of vital signs is the most prevalent U-Health application. Through regular monitoring, a detailed picture of patients's health can be developed and any physiological changes can be easily detected. It can also aid on monitoring of elderly gait and disable people; either monitoring of their stability or the health conditions. In addition, U-Health can be used on the medication administration. For example, reminding the recipient about when, how much, and what type of medication to take, etc. Furthermore, U-Health can also be helpful in remotely titrating the medicine to an appropriate amount and in appropriate time.

To realize U-Health services practically, a variety of U-Health systems and devices have been developed so far. However, as WBAN is a low power small area network, its service coverage is not wide. While, to facilitate the seamless U-Health services, the updates should be available anytime and anywhere without disruption. In addition, the authorized agents should also be able to archive the patient's earlier health care history anytime and

anywhere without any hindrance. It refers not only the properly maintained database access but also an easy access to them.

To facilitate the seamless U-Health services, it becomes important to integrate WBAN with other outgoing networks, like cellular networks, Wi-Fi networks, satellite networks, etc. Nevertheless, as WBAN possesses different set of characteristics and significantly differs from other networks in terms of applications, architecture, and deployment density; big challenges reside in the realm of uniform integration. Not only the link connections, instead, the integrated network also has to maintain end-to-end Quality of Service (QoS) along with other substantive parameters of data transmission.

Most of the existing outgoing networks, despite being advanced, do not meet some of the key requirements of U-Health. Service quality fluctuations in cellular networks due to poor indoor coverage, location of cell phone at the edge, and so on are clearly noticeable problems in cellular networks. Integration with Wi-Fi lacks the mobility support and ultimately loss the reliability. If the patients are required to transfer to the different locations; especially to outside premises or hospitals and wards, it is hard to maintain the seamless connection in Wi-Fi because of its local area coverage only. Moreover, since Wi-Fi operate in common Industrial, Scientific, and Medical (ISM) band, it is always prone to the interference. While, in case of satellite network, it always requires a line-of-sight with orbiting satellites.

An initiative research approach towards uniform integration of WBAN with various outgoing networks can provide a landmark in U-Health development. To address this issue, there could be various approaches. At the same time, an approach, integration of WBAN with femtocell deployed cellular network, which we discuss in this paper, could alternatively be simpler, more pragmatic, and one of the interesting and anticipated network ¹ solutions.

Femtocells are short-range miniature cellular Base Stations (BSs) typically deployed in indoor environment to compensate for poor coverage. In addition to the capacity provided by the cellular system, femtocell connects standard mobile devices to a mobile service provider's network using costumer's existing broadband connections, like Digital Subscriber Line (DSL), cable modem, and optical fibers. As the cellular network or the broadband internet connections have been widely deployed covering almost all areas, integration of WBAN with these network could interestingly satisfy major requirements of U-Health; provided that such network has appropriately defined policy layer that

¹With increased adoption of cellular communication services in U-Health and rise of femtocell deployment in cellular communication, it can be anticipated that femtocell deployed cellular networks could be one of the futuristic networks for U-Health.

dynamically manages an overall operation in an intelligent way: Self Organizing Network (SON).

The concept of femtocell and SON have already been a main stream idea in different networks. Even so, still there are some technical and commercial problems needed to be sorted before adopting it for U-Health. In this paper, we highlight the opportunities of such femtocell deployed SON for U-health; analyze both the technical and commercial challenges, and discuss some open issues. We also briefly discuss some related works and compare them with femtocell deployed SON.

II. U-HEALTH REQUIREMENT

To enable the U-Health services to be as smooth as possible, a number of design considerations needs to be met. WBAN should be designed on a practical way so that it can fit into people's lives in an unobtrusive manner. Biocompatibility between the device and human body should also be fully tested to ensure no adverse effects or reactions to occur. Moreover, great emphasis should be placed on data availability.

For the right diagnosis and right prescription medical personnel may need various updates with guaranteed QoS. A failure in timely delivery of the updates or delivery with an error can impact severely and sometimes may even risk the patient's life. Similarly, the portable sensor nodes should also be energy efficient and miniaturized in design. Aside from that, as human body also presents various adverse fading effects to the WBAN channels and the channel characteristics can also vary with body size and posture [6], and as WBAN employs low power sensor nodes with less computational capacity and buffer size, there might exist the risk of data drop and data error. Hence, as a whole, all these requirements demand special care on design of an efficient WBAN.

An approach towards integration of WBAN with outgoing networks is also equally important as mention above. To achieve this goal it demands a design of an overlay network. Overlay network can be thought of as network built on top of one another and connected by virtual or logical links (each of which correspond to a path, perhaps through many physical links) in order to implement network services that are not available in one another [7].

As precursors to the future architecture of the U-Health, overlay network mentioned here is not supposed to create link connections only; instead it must ensure the seamless connection, transparent access to either networks, seamless roam across those networks, self optimization, self deployment, and more importantly the end-to-end QoS support for diverse range of WBAN applications without unduly increasing complexity and decreasing performance.

III. U-HEALTH DEVELOPMENT TRENDS

A lot of active research is being conducted for betterment of WBAN both from academia and industries. For example, the project of WBAN technology development in Electronics and Telecommunication Research Institute (ETRI) Korea is focusing on the development of WBAN Physical (PHY) and Medium Access Control (MAC) technology using variable data rate [8]. Similarly, Mobile Health care project (MobiHealth) [9] funded by the European Commission is acting on reforming all the layers of general health care networks to allow patients to be fully mobile whilst undergoing treatment. MIT Media Lab is

developing MITHril to give a complete insight of human-machine interface [10]. Human Interface Technology (HIT) lab is focusing on quality interfaces and innovative wearable computers [11]. Aeronautics and Space Administration (NASA) in USA is developing a wearable physiological monitoring system for astronauts called LifeGuard system [12].

A number of U-health development concepts has also been proposed throughout. We can trace some of the prior works in [13],[14],[15],[16]. The LOBIN project in [13] allows monitoring several physiological parameters and tracking the location of a group of patients within hospital environments. It consists of a set of physiological sensors and a wearable data acquisition device (WDAD). WDAD processes the data received from the sensors and transmits in wireless channel to the distribution points (DP). DP further transmits data via a wired gateway to the management subsystem.

In [14], Telehealth networking infrastructure has been proposed. The hierarchical architecture in Telehealth contains sensors, motes, On-Body Terminals (OBTs), and central server. The server can monitor the functionality of individual patients and can reconfigure OBTs and associated nodes according to the real-time needs. In the WBAN sublayer, the nodes communicate with OBT using IEEE 802.15.4 communication protocol. While, the OBT transfers data to a remote server by using either Wi-Fi or Bluetooth.

In [15], architecture of remote patient monitoring service using heterogeneous wireless networks has been presented. In this system, a patient-attached monitoring device collects biosignal data from the sensors and transmits the data through the Radio Access Network (RAN) to the health service provider. The architecture has been designed on such a way that the WBAN integrates with both the Wi-Fi and cellular network (mobile WiMAX).

In [16], it has provisioned mobile broadband data connectivity for emergency telemedicine applications in indoor environment. WBAN is integrated with cellular network and internet via femtocell. It has provisioned the transmission of locally generated emergency telemedicine media streams as multiplexed multimedia services in outgoing networks.

Through keen observation, it can be envisioned that though these works have tried to solve integration schemes; none of them can simultaneously satisfy all the requirements of an overlay network as mentioned earlier. Even though femtocell deployed network has tried to overcome some of the limitations, blindly categorizing the streams and mapping the traffics with another network's QoS module could not satisfy the QoS demand of WBAN properly.

IV. FEMTOCELL DEPLOYED SON FOR U-HEALTH

A. Femtocell

As mentioned earlier, femtocells are short-range, low-power, and low-cost miniature BSs typically deployed in indoor environment by end user themselves to improve coverage in cellular networks. Femtocells operate in licensed spectrum and also connect standard mobile devices to a mobile service provider's network using customer's existing broadband connections. Recently, femtocells have been receiving much attention as their deployment renders many advantages to both the end-users and mobile service providers. For the mobile service providers, deployment of femtocells provides a very cost effective means

TABLE I
COMPARISON OF PRIOR WORKS WITH FEMTOCELL DEPLOYED SON FOR U-HEALTH

Project	Network limitation	Service limitation	Solution
Lobin project	Simple static hospital network scenario with no scalability support.	Once the application is fixed, it cannot be altered at run-time.	Flexible network management ensures the flexibility of the monitoring and mobility. SON ensures the application-adaptation at run-time.
Telehealth	Simple static hospital network scenario with no mobility support.	QoS effect in the ad hoc network such as reliability is not specified.	The hierarchical network architecture ensure the service availability and network communication in a more efficient way.
Remote patient monitoring service	Service quality fluctuations due to node at edge, changing network load patterns, inter and intra cellular interference, and so on.	No end to end QoS definition and QoS provisioning system.	Seamless robust connectivity with femtocell as a bridge between broadband internet and cellular networks. Dynamic QoS provisioning with MAC-to-MAC connection.
Mobile broadband data connectivity	Static network. No overlay network solution.	Direct QoS mapping (telemedicine media streams as multiplexed multimedia services).	Dynamic overlay network with SON and dynamic QoS provisioning with MAC-to-MAC connection.

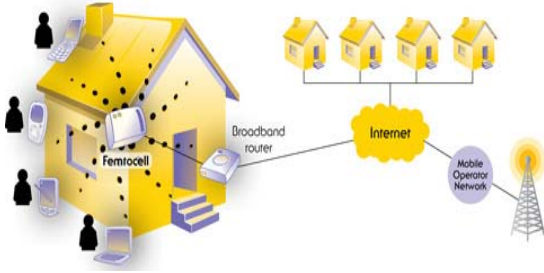


Fig. 1. Femtocell concept [17]

of improving indoor coverage. Additionally, such deployments offload significant proportion of the traffic to the IP backhaul. While, for the end-user, the use of indoor femtocells enhances user-experience by providing seamless services. A conceptual overview of femtocell is shown in Fig. 1.

B. SON

Recently, the SON concept also has been widely studied, for example in mobile ad hoc networks [18]. SON can be defined as a set of functionalities that enable the automation of network operations by minimizing manual intervention or configuration. The main goal of SON in an integrated network, however, is to provide a flexible and automated control plane so that the services even in a complex mesh of different networks could be handled in self-organized way. To achieve better service quality in an end-to-end manner and to ensure easy usage of communications services, SON can be thought of as empowered with the capabilities of intelligent traffic identification, effective service classification and prioritization, topology discovery, error discovery and self healing, etc.

C. Opportunities

Meanwhile, femtocell and SON concepts have progressed from prototypes to requirements of different cellular networks. Due to an interest from operators (such as Next Generation Mobile Network (NGMN) alliance) and standardization bodies (such as 3GPP, Femto Forum, Broadband Forum, IEEE 802.16m, WiMAX Forum, GSMA, etc.), deployment of femtocell with SON characteristics is expected to be a major part of the future cellular networks [19],[20]. Consequently, with the increased adoption of

cellular networks for U-Health, deployment of femtocell deployed SON for U-Health can also be anticipated to rise.

Logically the femtocell deployed SON for U-Health can be viewed as combination of three regions: WBAN region, femto region, and the outward region. WBAN region deals with the core health care applications; smart phone acting as a coordinator. Femto region, more specifically the femtocell, on the other hand, has dual function. First, it receives the updates from the smart phone and forwards it to the local healthcare section via local gateway by using either wired or wireless interface. Second, it forwards the updates to outer region, internet or mobile service provider's network, via broadband connections. The smart phone also acts as an interface towards macro BTS such that if things go wrong or during the mobility to out of the femtocell region, it can turn to cellular operators for support. Macro BTS acts as bridge between smart phone and Mobile Switching Center (MSC). While, MSC can store the data and also can define or monitor the services. As a whole, with this network set up, authorized agents or the physician can access updates directly through internet, MSC, or other servers anytime and anywhere. The overlay network thus can be logically viewed as the combination of three different sublayers: U-Health network sublayer, SON sublayer, and application sublayer. Figure 2 shows its basic concept.

With femtocell integrated SON for U-Health, it is not difficult to envision that the U-Health paradigms can be reached at least through the following two mechanisms.

- Ubiquitous self organizing link connection to support full-fledge autonomous and optimized communication between diverse networks, and
- end-to-end QoS support without unduly increasing complexity and decreasing overall performance (challenges in the following subsection).

The comprehensive table in I presents the limitation of basic network architecture and services offered by the prior works and highlights the solution that could be provided by femtocell deployed SON.

More specifically, with femtocell deployed SON, following opportunities could be exploited for U-Health.

1) *Ubiquitous coverage*: As cellular networks or broadband connections are widely deployed, ubiquitous coverage can be assumed with the deployment of femtocell. Additionally it could also be possible to deliver cellular like services to the regions where existing cellular coverage is limited or absent even if the

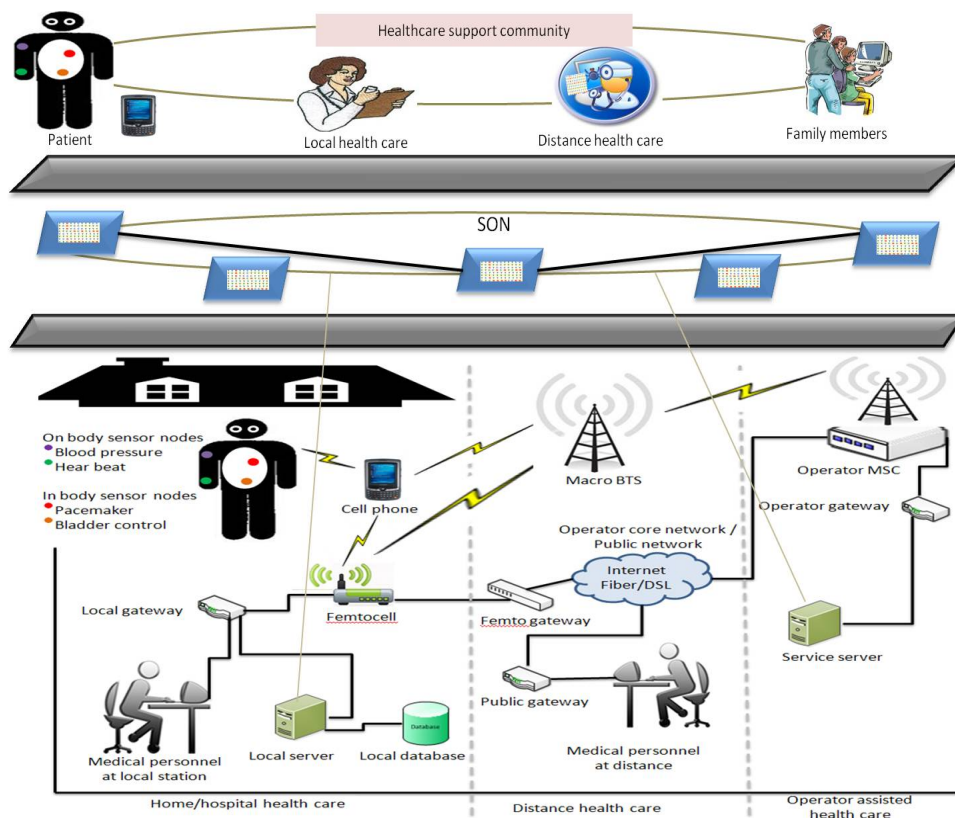


Fig. 2. Femtocell deployed SON for U-Health

broadband connection is available.

2) *Self organizing link connection and self optimization*: Deployment of SON assists on self organizing link connection, transparently to the user. The automated control plane in SON delivers provision for integration, self optimization, and synchronization of the tasks in the different planes of the networks.

3) *Energy saving*: Owing to the relatively shorter distance between smart phone and femtocells, smart phones can make their uplink transmissions using much reduced power and thus can save energy. In addition, optimized network with efficient transmission management system always address energy efficiency in WBAN.

4) *Reliability*: Patients can freely move across femto regions and macro regions; seamless handoff from macro cellular network to femtocell and vice versa. In addition, SON always look after traffic identification, error discovery, performance management, and QoS management to ensure reliable communication. Low signal strength received from an outdoor macro BS inside home/hospital environment is over come. No interference with ISM band like in Wi-Fi exist. Even if the things go wrong or during the mobility to out of the femtocell coverage, it can turn to cellular operators for support.

5) *Cost benefit*: Femtocell deployments will reduce the operating and capital expenditure costs for operators. While, reduced amount of traffic on expensive macrocell network saves expenditure for clients.

D. Challenges

The legacy femto BSs are deployed by end users themselves without any prior network planning and are also supposed to be self-initialized and self-organized. The primary challenges lie in

allocating resources, designing proper access control mechanisms, QoS management, managing Radio Frequency (RF) interference and mobility, and maintaining precise timing and synchronization over the network. On top of that the cost of the femtocell should also be in the affordable range. In what follows, we shall comprehensively analyze the most prevalent issues.

1) *Access control and resource allocation*: In femtocell deployed U-Health, during admission control it has to look after both way networks and should handle the admission control and resource allocation in more clever way. It has to deal with two types of access control and resource allocation: network level and service level. In first, it has to determine whether to allow or restrict users from femtocell access: open access (public) or closed access (private). Though open access is more suitable, it is commercially disadvantageous and technically challenging. The non paid and ordinary client beyond health care might create disturbances. While in closed access, some of the power leaked will be sensed as interference by passing macro cell users, thus decreasing the signal quality. On the other hand, in service level access control and resource allocation, it should admit the request only after fully analyzing service information, for example, QoS parameters, resource utilization, resource availability, urgency, etc. Hence care should be taken beforehand during designing the access control and resource allocation schemes.

2) *End-to-End QoS*: As two or more than two types of network each having different protocol stacks are integrated, the end-to-end QoS support is always a challenging job. While the QoS support has been extensively studied in cellular networks and wired networks, current WBAN does not support QoS very

well. Throughput, delay, jitter, and loss/error are the main QoS parameters in traditional networks. While, data criticality comes as an additional parameter in WBAN. In addition the available energy level also comes as another substantiating parameter. The traffics are also required to be classified and prioritized differently in WBAN. For example, in cellular networks like WiMax the traffics are categorized into different service classes as real time, non real time, best effort, or the background traffics. While, in WBAN, the classification could be emergency alarm (e.g. alarm signal at detecting extremely life threatening condition), real time periodic (e.g. multi-media related traffic during diagnosis or surgery), on demand (e.g. feedback in response to command from higher layer), non real time periodic (e.g. feedback in some time interval but with no end-to-end delay constrain), and best effort (e.g. patient's record file transfer, physician's note transfer etc).

To provide requested QoS to the differentiated services, differentiated service and prioritization schemes have been provisioned in both the cellular and broadband networks. However, blindly categorizing the streams and mapping the traffics with one another QoS module could not satisfy the QoS demand of WBAN (e.g emergency traffic mapped to real time traffic could be problematic). Hence, for the sake of fine-grain QoS assurance newly defined QoS parameters and end-to-end QoS solution with MAC-to-MAC connection protocol is essential. Similarly, in some cases application's criticality and the QoS parameters even need to be identified and defined by medical personnel according to their needs. Hence the flexibility while tuning the MAC parameters should also be considered.

The QoS performance is also largely affected by condition of broadband connection. The costumer's broadband connection can be different from operator's network or the authorized agent's network and vice versa. In addition, various factors like network load and efficiency of routing in intermediate network nodes also affects the QoS performance. Hence, it is essential that the system should be smart enough to analyze those parameters in advance and the intermediate nodes should also be aware of those parameters and capable to support the protocol in consistent manner.

3) *RF interference and mobility management*: As femtocells utilizes the spectrum already allocated for its macrocell, there always arises an issue of interference. There will be fewer femto-cell interference problems if the femtocells use a separate carrier frequency to the surrounding macro networks. But this is not a proper solution, as there always remains the probability of inefficient resource utilization. On the other hand, if the femtocells use the same carrier frequency, the more complicated scenarios arise. This scenario provides the greatest level of spectrum efficiency; however, it also raises greatest challenges to the interference management systems. Similarly, as there exist the possibility of high volume of femtocells in close proximity, especially in hospital scenario, mobility management (handover management) also arises as the challenging job. New design solution is required to avoid frequent inter-femto handover. On the other hand, if there is strong inter-femto interference, it is desirable to have scheme that could assign different carrier to neighboring femtocells.

V. CONCLUSION

Provided with SON characteristics, deployment of femtocell to bridge WBAN with widely deployed cellular and broadband connections can provide the landmark in U-Health development. Even so, still there are some technical challenges like requirement of proper end-to-end QoS provision, insertion of proper admission control and interference mitigation schemes, etc. needed to be sorted before adopting it for U-Health. In this comprehensive paper, we discussed these issues and highlighted the opportunities and challenges. We also briefly discussed some prior works and presented how femtocell deployed SON could overcome such issues.

REFERENCES

- [1] C. Otto, A. Milenkovic, C. Sanders, and E. Jovanov, "System architecture of a wireless body area sensor network for ubiquitous health monitoring," *Journal of Mobile Multimedia*, vol. 1, no. 4, pp. 307–326, 2006.
- [2] H. Wang, D. Peng, W. Wang, H. Sharif, H. Hwa Chen, and A. Khoynzad, "Resource-aware secure ecg healthcare monitoring through body sensor networks," *Wireless Communications, IEEE*, vol. 17, no. 1, pp. 12–19, february 2010.
- [3] M. Li, W. Lou, and K. Ren, "Data security and privacy in wireless body area networks," *Wireless Communications, IEEE*, vol. 17, no. 1, pp. 51–58, february 2010.
- [4] R. Rashid, S. Arifin, M. Rahim, M. Sarijari, and N. Mahalin, "Home healthcare via wireless biomedical sensor network," in *RF and Microwave Conference, 2008. RFM 2008. IEEE International*, dec. 2008, pp. 511–514.
- [5] R. King, M. McGrath, B. Caulfield, and G.-Z. Yang, "Capsil common awareness and knowledge platform for studying and enabling independent living," in *Body Sensor Networks (BSN), 2010 International Conference on*, june 2010, pp. 283–288.
- [6] G. Zhou, J. Lu, C.-Y. Wan, M. Yarvis, and J. Stankovic, "Bodyqos: Adaptive and radio-agnostic qos for body sensor networks," in *INFOCOM 2008. The 27th Conference on Computer Communications. IEEE*, april 2008, pp. 565–573.
- [7] http://en.wikipedia.org/wiki/Overlay_network, accessed Nov 14, 2011.
- [8] http://www.etri.re.kr/eng/etri/sub02/sub02_4112_7.jsp, accessed Nov 14, 2011.
- [9] <http://www.mobihealth.org/>, accessed Nov 14, 2011.
- [10] <http://www.media.mit.edu/wearables/mithril/>, accessed Nov 14, 2011.
- [11] <http://www.hitl.washington.edu/home/>, accessed Nov 14, 2011.
- [12] <http://www.nasa.gov/centers/ames/research/technology-onepaggers/life-guard.html>, accessed Nov 14, 2011.
- [13] G. Lopez, V. Custodio, and J. Moreno, "Lobin: E-textile and wireless-sensor-network-based platform for healthcare monitoring in future hospital environments," *Information Technology in Biomedicine, IEEE Transactions on*, vol. 14, no. 6, pp. 1446–1458, nov. 2010.
- [14] F. Dabiri, T. Massey, H. Noshadi, H. Hagopian, C. Lin, R. Tan, J. Schmidt, and M. Sarrafzadeh, "A telehealth architecture for networked embedded systems: A case study in in vivo health monitoring," *Information Technology in Biomedicine, IEEE Transactions on*, vol. 13, no. 3, pp. 351–359, may 2009.
- [15] D. Niyato, E. Hossain, and S. Camorlinga, "Remote patient monitoring service using heterogeneous wireless access networks: architecture and optimization," *Selected Areas in Communications, IEEE Journal on*, vol. 27, no. 4, pp. 412–423, may 2009.
- [16] E. Mufungwa, Z. Zheng, J. Hamalainen, M. Husso, and T. Korhonen, "Exploiting femtocellular networks for emergency telemedicine applications in indoor environments," in *e-Health Networking Applications and Services (Healthcom), 2010 12th IEEE International Conference on*, july 2010, pp. 283–289.
- [17] <http://femtoforum.org/fem2/>, accessed Nov 14, 2011.
- [18] C. Makaya, A. Dutta, S. Das, D. Chee, F. Lin, S. Komorita, H. Yokota, and H. Schulzrinne, "Service continuity support in self-organizing ims networks," in *Wireless Communication, Vehicular Technology, Information Theory and Aerospace Electronic Systems Technology (Wireless VITAE), 2011 2nd International Conference on*, 28 2011–march 3 2011, pp. 1–5.
- [19] M. Z. Chowdhury, Y. M. Jang, and Z. J. Haas, "Network evolution and qos provisioning for integrated femtocell/macrocell networks."
- [20] L. Eastwood, S. Migaldi, Q. Xie, and V. Gupta, "Mobility using ieee 802.21 in a heterogeneous ieee 802.16/802.11-based, imt-advanced (4g) network," *Wireless Communications, IEEE*, vol. 15, no. 2, pp. 26–34, april 2008.