AmbNet: Project Description

WiFi networks have achieved major penetration in both domestic and enterprise markets throughout the world. They constitute the largely dominant method of broadband wireless access and, unlike their cellular counterparts, have established 802.11 technologies as a true global standard. The sheer volume of WiFi products has ensured that chipsets are available at commodity prices.

However, WiFi networks suffer from major drawbacks: 1- their **limited range** due to the transmit power restriction in unlicensed bands; 2- the random access, **shared medium** nature of the MAC layer which tends to collapse at high traffic loads (more than 30% offered traffic); 3- **coverage area gaps** due to walls, obstacles, limited range and the lack of rigorous planning at deployment; 4- **unpredictable interference** in unlicensed bands.

To be able to support multiple wireless synchronized streams of music to different zones of a house or building, Californian equipment maker Sonos designed SonosNet, a proprietary mesh network protocol exploiting the WiFi physical layer, where the mesh aspect is exploited to achieve extended range.

In a similar spirit, AmbNet is a next generation self-organized, resilient and self-healing multimedia streaming wireless network technology built on top of WiFi physical layer chipsets and capable of co-existing with multiple overlayed conventional WiFi networks. In AmbNet, a distinction is made between infrastructure devices (access points) and client devices (information sources or sinks), although an access point can also simultaneously act as a client device in some cases. Access points are AmbNet specific devices which can be modular in nature and incorporate multiple WiFi ports (to address more than one WiFi frequency channel simultaneously). Client devices can be AmbNet specific, or can be conventional WiFi-equipped devices (such as an iPod, smartphone or other) running AmbNet software.

To address range, coverage, and interference, AmbNet leverages a proprietary mesh network technology which incorporates macrodiversity. The latter feature is a combination of synchronous (multiple access points receiver or transmit the same packet simultaneously on the same channel) and asynchronous diversity (multiple routes through the mesh). Unlike conventional WiFi, the focus of AmbNet is session-oriented, and more specifically on constant bit rate (CBR) and variable bit rate (VBR) connections, implementing traffic classes and ensuring a degree of quality of service in uncertain environments.

The goal is to realize network technology which allows rapid ad hoc deployment, yet provides resilient, reliable operation in the presence of overlayed networks and access point failure, yet is capable of sustaining multiple simultaneous delay-sensitive high-bandwidth streams, such as HD video or videoconferencing.

AmbNet implements a contention-free protocol, such as in 802.11's point coordination function (PCF) or 802.16e's hybrid coordination function controlled channel access (HCCA). However, unlike those existing techniques, channel access (as well as macrodiversity management) is not centralized, but achieved through engineered emergent behavior. Proven minimalist multi-agent techniques developed in our lab will be levaraged to allow the access points to coordinate among themselves with minimal control signaling. By simply observing traffic and performing occasional handshakes with clients, access points are able to infer decisions taken by neighbors as well as ascertain the state of external interference (from e.g. overlayed networks), leading to implicit global organization. Such agents are used for channel / time slot assignment (and thus interference management), macrodiversity connection management, and power control. The system is intrinsically self-organizing and self-healing, continuously reevaluates channel assignment to avoid external and self-interference, and exploits macrodiversity for robustness, range extension, and elimination of coverage gaps.

The self-organization techniques at the core of AmbNet have very broad applicability and are related to the recent push in wireless research (such as in the SOCRATES European project) on self-organized networks (SON) functions. However, the approach here is somewhat different and could constitute the seed of a rich branch of research. Thus, exchange and synergy with other research teams in universities is both welcome and relevant in order to quickly develop the raw potential of these core ideas.

Relation to emphasis area(s)

The proposal is related to multiple emphasis areas, but pertains more directly to *radio network management and systems innovations.* Indeed, the major innovations here are systemic in nature and deal primarily with radio resource management using distributed intelligence. Such techniques, which are variously associated with terms such as swarming and ant colony optimization, are very rarely studied at the lowest layers of the network (such as PHY and MAC).

The proposal also can be associated with *energy improvement,* since the combined use of macrodiversity and power control through the distributed intelligence scheme will tend to **globally optimize** power distribution through the network while minimizing self-interference.

AmbNet relies on physical layer macrodiversity, and as such, relates to *radio signal propagation and processing.* Also, because of macrodiversity, MAC-layer improvements (including the contention-free operation and the agent-based resource allocation), and the possible use of multiple radio interfaces at access points, the proposal exhibits significant linkage to *radio modem innovations.*

Commercial viability / market value

The widespread success and ubiquitous nature of WiFi networks is well established. However, the lack of QoS control becomes an increasingly serious impediment as the unlicensed bands get more and more crowded. While 802.11e attempts to address QoS, it is currently implemented in very few products, is not combined with mesh networks, and is limited because of its centralized nature at one access point and lack of coordination between access points. Unlike traditional WiFi networks, AmbNet access points act collectively in striving to offer the requested QoS levels in a dynamic environment, and this constitute a form of cognitive network.

Three major markets are considered. In enterprise markets, WiFi networks are commonplace and are increasingly called upon to support VoIP calls and, eventually, SIP video calls and videoconferencing, as well as high-quality video streaming. The latter applications are currently less common in an enterprise setting because they tend to break down when the network is busy. There are, however, cases of large enterprises or universities that have leveraged their WiFi network to implement mobile VoIP access, resulting in serious QoS issues and unpredictable performance. In one extreme case, a university relied on such a wireless VoIP scheme for emergency communications by its security service.

A low-cost easily deployed overlaid network such as AmbNet becomes an attractive solution due to its reliability and fault tolerance. Furthermore, it still represents a fraction of the cost of a wired network in many scenarios and provides mobility and flexibility to services traditionally associated with fixed, wired workstations. Finally, it is conceivable to dedicate a portion of AmbNet's bandwidth to traditional WiFi traffic (using a contention period), thus eliminating the need for overlaid WiFi networks if they don't already exist.

For major events and trade shows, a rapidly deployed low-cost wireless network is a definitive plus, and the ability to offer hundreds of live video feeds in parallel to attendees over their smart phones is attractive.

The domestic market should also not be overlooked. In some ways, what is proposed here is a next generation, video-enabled version of the Sonos platform, allowing the streaming of multiple audio and video (HD) streams simultaneously to different areas of the house.

Artifact creation and potential commercialization

In previous research, we have demonstrated the feasibility of the self-organized cognitive network concept in the context of a generic cellular network with a high degree of macrodiversity. Thus, a high density infrastructure was assumed. This proof of concept work had the following outstanding features: 1. It was characterized by minimal signaling and deceptively simple resource management algorithms relying on multi-agent techniques. 2. Without explicit centralization of information or decision power, the system achieves near-optimal resource allocation balance from a global standpoint. 3. The system is very robust to dynamic changes of all kinds, e.g. it adapts organically to compensate for a synstation failure (much like dynamic internet routing algorithms automatically re-route upon node failure). 4. The addition of a new dimension in the resource allocation problem can be performed in an isolated manner without affecting the performance of existing dimensions, which react and adapt implicitly to any coupling. Because of this remarkable property of such multi-agent systems, we were able to add one layer after the other of resource management processing: a. macrodiversity connection management; [1] b. channel allocation and interference management; [2], [3] c. cooperation among pairs and trios of users; [4] d. dynamic power control. [5]

Because of this pre-existing proof-of-concept research, the adaptation and design work for AmbNet is considerably reduced. We already have an extensive large-scale simulation platform which is currently being used to study the applicability of the multi-agent techniques to LTE cellular networks. Based on this, we foresee the following steps towards commercialization:

1. Fork of existing platform to create a network simulator for the AmbNet / WiFi context;
2. Design of multi-agent algorithms for channel allocation and macrodiversity, as well as MAC protocols appropriate for AmbNet goals;
3. Fine-tuning of algorithms through simulator;
4. File patent application(s);
5. Publish papers – create buzz in academia
6. Develop access point hardware prototype, largely based on off-the-shelf components, and incorporate multi-agent algorithms and MAC protocols as firmware;
7. Develop client hardware prototype and / or smartphone client software
8. Field tests for enterprise and domestic scenarios
9. Armed with functional prototypes, create startup and obtain funding for next phase
10. Develop production version of hardware and software
11. Create buzz on Internet
12. Organize mass production with appropriate partners
13. Establish distribution network
14. Take to market

Steps 1 through 7 can be completed within a year by the team of 3. Steps 8 through 13 require further thought at some point.

[1] P. Leroux, S. Roy and J.-Y. Chouinard, "An agent system to manage mobile connections in a distributed base station scheme," in Proc. Pers. Indoor and Mobile Radio Comm. Symp. (PIMRC), Helsinki, Sept. 11-14, 2006.

[2] P. Leroux, S. Roy, and J.-Y. Chouinard, “A multi-agent protocol to manage interference in a distributed base station system,” Advanced Technologies for Communication (ATC) Conf., Hanoi, Vietnam, Oct. 5-8, 2008.

[3] P. Leroux and S. Roy, “The impact of interference in a distributed base station scheme managed by an agent system,” in Proc. Internat. Workshop on Wireless Mesh and Ad Hoc Networks (WiMAN), Aug. 16, 2007, Kahuku, Hawai’i.

[4] P. Leroux and S. Roy, “Distributed Power control with multiple agents in a distributed base station scheme using macrodiversity,” Proc. International Symposium on Stabilization, Safety, and Security of Distributed Systems (SSS 2009), Lyon, France, Nov. 3–6, 2009.

[5] P. Leroux, S. Roy, and J.-Y. Chouinard, “Synergetic cooperation in a distributed base station system,” Proc. Pers. Indoor and Mobile Radio Comm. Symp. (PIMRC), Cannes, France, Sept. 15–18, 2008.