Simulation Evaluation of the IEEE 802.11ac ad-hoc Network for Voice Communication in Emergency Scenario

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Abstract— The paper presents simulation study of communication system consisting of mobile nodes during crisis situation scenario. Nodes' network interfaces support IEEE 802.11ac standard in ad-hoc mode, while devices operate under control of Google Inc. Android operating system. Overview of current Wi-Fi techniques was described, with an indication of further standard evolution. Limitations of current Wi-Fi ad-hoc mode implementation in Android were addressed, with emphasis on ongoing research projects on overcoming specific restrictions: Wi-Fi Peer-to-Peer extension and multi-hop transmission. Evaluation of network efficiency with Voice over IP service activity during an emergency scenario was performed in simulation environment. Lack of cellular connectivity, external power access and no access to special communication equipment during rescue operation were assumed. Obtained results show insignificant impact of service realization on network resources utilization, low maximum end-to-end packet delivery delay and jitter values during continuous telephone conversations. Thus, described assessment shows a high degree of IEEE 802.11ac ad-hoc network applicability in scope of basic voice communication service realization in case of absence of usually ubiquitous cellular infrastructure, with use of typical communication equipment.

1. INTRODUCTION

We face crisis situations everyday and are immediately informed on every such crisis by the mass media. These events take place in both stable and rich countries such as France and unstable, such as Ukraine. The attack on Charlie Hebdo editorial office or the racket attack on Mariupol are different examples of accidents, but they have something in common. In both the first and second case, the access to mobile telephone services was limited. In the first case, due to overload of the mobile network and its subsequent switch-off, and in the second case, due to failure of the fixed-line network. Even more severe situations occurred in 2004 in Indonesia and in 2011 in Japan, where the tsunami caused deaths of hundreds of thousands of people, and in the areas covered by the disaster, access could not be provided to telephone services which would be very useful in such a situation. Due to the damages of the power plants operating in an integrated power system over a wide area of Japan (even that not directly affected by the tsunami), a black-out occurred.

Development of the Wi-Fi standards results in their throughput similar to that of Ethernet networks. Today, it is difficult to imagine a TV, camera or smart phone without Wi-Fi — they are as common as the very telecommunications service. The range of a home-edition of Wi-Fi radio interface is limited to several dozens of meters and ensures a quick exchange of data between different devices. The unit price of manufacture of a Wi-Fi transceiver allows for using this solution even as a single-use device [1].

In the above mentioned crisis situations, the only devices that could be used for a certain time after the event included smart phones and Wi-Fi laptops, enabling Ad-Hoc cooperation. Wi-Fi devices networks are mostly used as backhauls, confronting the infrastructure of wireless routers. However, in emergency situations, where no power supply or mobile network access can be provided, the Ad-Hoc Wi-Fi operation seems the only solution to ensure telecommunications services such as IP telephony or messaging. Owing to that, people would be able to communicate [2].

Where the mobile network infrastructure is not available, Wi-Fi devices are the only generally accessible means of communication for civilians. In the case of laptops, Ad-Hoc operation can be easily forced, whereas in not all the smart phones Ad-Hoc operation is enabled on Wi-Fi interfaces. Nevertheless, in new smart phones, additional software for Ad-Hoc operation can be installed to provide, e.g., VoIP service or data exchange.

In the world-wide standardization community, the belief that radio communications means should be universal is increasingly popular. This should ensure data exchange between different network techniques and operate even without network infrastructure. The devices and systems should be able to exchange data between them and by means of relay, through intermediate points.

In the near future, the developing Wi-Fi technology, the processing power of smart phones and capacity of their batteries will enable adaptation of Wi-Fi network to Ad-Hoc operation, which should significantly improve interoperability of the systems used, and positively in uence public safety.

In addition to the benefits, risks and losses are possible as well, which result from the unauthorized and hostile activities. The near future will determine development directions in this area. The further part of the paper presents the basic technical issues determining the Wi-Fi technology development along with its direction. As the next step, the status of Android system dominance on the telecommunications market, and its development toward implementation of the common Ad-Hoc operation was analyzed. Then, reference was made to efficiency of Wi-Fi network in relation to systems adapted to transfer telephone services in IP network.

2. TECHNICAL ISSUES DETERMINING DEVELOPMENT OF WI-FI TECHNOLOGY AND SPECIFYING ITS DEVELOPMENT DIRECTION

It is hard to believe, but today Wi-Fi technology is already adult, and its first standards were elaborated 18 years ago. At present, one can hardly imagine computer networks without Wi-Fi and laptops without this standard cards. According to one of the largest companies selling hardware, in Poland there are no no more laptops without a Wi-Fi card. It is not surprising, as this technology facilitates our life and, what is more, enables provision of services, including the Internet TV. However, to ensure such services, technical parameters must be compliant with service quality standards, and the operational mechanisms are the result of application of various patents.

In the field of mobile technology innovation, Koreans are the leading manufacturers. The global patent market share in the 3rd quarter of 2014 is shown in Fig. 1 [3]. For the Wi-Fi technology market, data from the 4th quarter of 2011 are available for 802.11ac standard — in this case the American company Qualcomm was the leader [4] Fig. 2. Selected Wi-Fi characteristics are included in Table 1. All solutions have a range of approx. 50 meters indoors and approx. 100 meters outdoors. Wi-Fi technology develops mainly toward provision of increasing transmission rates and ranges, as well as easy use.

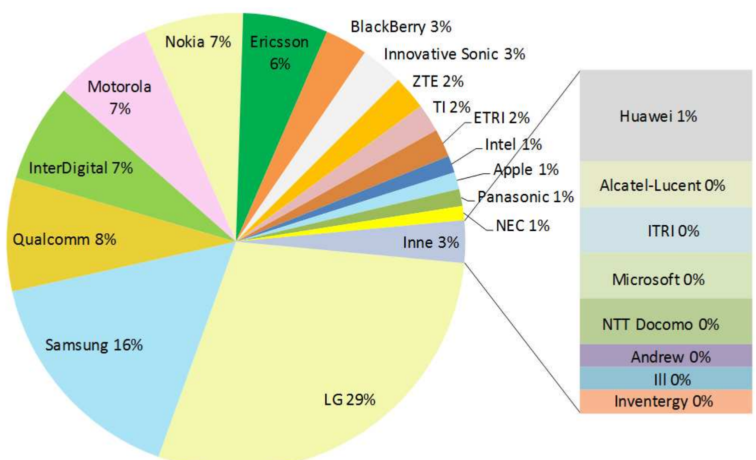

Figure 1: Innovativeness of companies in the 4th generation systems.

Wi-Fi interface was created due to the need to eliminate the Ethernet cable, whereas the transmission mechanisms remained in the same form, i.e., adapted to the computer data. This is why the performance of time-dependent services, e.g., telephony has to face efficiency constraints of radio channels sharing.

This limitation is overcome by other technologies such as WiMAX or LTE. However, WiMAX finally lost the battle for the market with Wi-Fi technology and did not find acceptance in smart phones and laptops. Standard 802.11e with the data priority-dependent access for transmission of E-DCF (Enhanced Distributed Coordination Function) or access allocated in the querying mechanism or HCF (Hybrid CF) is the solution aimed at introducing control mechanisms with access to a radio channel with priorities.

In environments, which are characterized by high density level of devices, and which can occur especially in crisis situations in heavily urbanized areas, increasing the efficiency of exchanged data streams is an issue worth an additional investigation. Proposed technique consist of optimal power

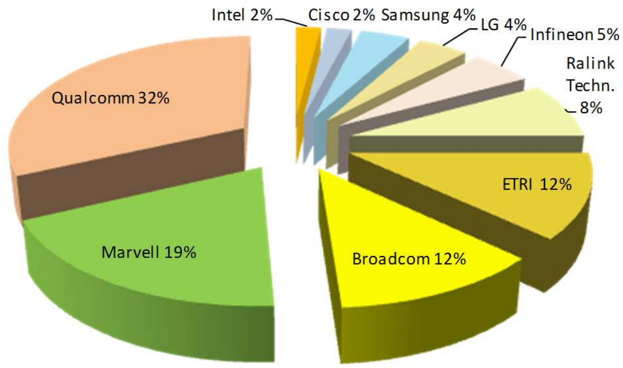

Figure 2: Innovativeness of companies in 802.11ac systems.

Table 1: Characteristics of Wi-Fi standards.

Std	Channel [MHz]	Throughput [Mb/s]	Bandwidth [GHz]	Range [m]
a	54	20	2.4	100
b	11	20	2.4	100
g	54	20	2.4	100
n	65/135	20/40	2.4/5	100
ac	86.7–780	20–160	5	100
ad	6750	2160	60	10

control procedures usage, which were developed and thoroughly discussed in [5]. The proposed mechanism allows to increase the capacity of transmission network, reducing power consumption at the same time. The latter feature is particularly important in crisis situations, where power conservation is crucial. The utilized algorithm is based on a nodes' signal to noise ratio metric, which is transmitted between networks nodes, and estimation of the optimal power for the specific data transmission path. Results of conducted simulation experiments indicate that approximately 30 percent increase in total physical capacity is possible to achieve, which noticeably improved quality of network services. At the same time, most stations work with reduced transmitter power level with respect to standard power level, even up to three-fold power level reduction.

3. GSM SPEECH CODING

Currently, a few speech codecs are used for the telephony, whose properties are shown in Table 2. Analog samples with duration of 20ms are subject to coding, and are subsequently coded by codecs. As a result, frames with different lengths (col. 2) are received and streams with different bitrate are generated (col. 3).

Table 2: Codecs used in GSM.

Codec type	Number of bits in sample	Transmission rate [kbs]
Half Rate (HR)	112	5.6
Full Rate (FR)	260	13
Enhanced FR (EFR)	244	12.2
Adaptive Multi Rate (AMR)	95/103/118/134/148/159/204/244	4.75–12.2
Adaptive Multi Rate — WideBand		6.6–12.65/14.25–23.85

4. AD-HOC COMMUNICATION IN ANDROID DEVICES

Despite the availability of Wi-Fi standard in most, if not all the devices operating under Android system, some operation modes are not natively supported by the operating system. The entry on the intention to have support for Ad-Hoc mode already appeared in January 2008, on an official bug tracking system for Android system, whereas 6 years later, on 25 December 2014, it was granted the status of being "obsolete" [6, 7]. Meanwhile, this entry was supplemented more than 6 thousand times. In accordance with the current, official source code for Android system, the entries concerning the network in IBSS mode (Independent Basic Service Set) are ignored in the process of creating a network list when scanning the environment [8].

It should be noted that it is possible to compile the modified version of the system or substitute wpa supplicant application (on some devices it was sufficient to change ap scan parameter in wpa supplicant.conf configuration file) with a modified version ignoring IBSS ag and allowing association with Ad-Hoc network. However, this type of interference requires at least unlocking the access to system partition, which is usually connected with the loss of warranty. Modifications obtained from untrusted sources entail potential risk of device infection with malware and in many cases (if bootloader, the system kernel and the package of system and additional software are modified) partial loss of the device functionality may follow, even if the developer assures that the software is adapted to the given hardware version. The current state of development of Android system extensions (4.2.2, 4.3, 4.4, 5.0) containing support for Ad-Hoc operation (native IBSS support and Wi-Fi Direct), including source code, required improvements and technical information for developers can be found in [9].

For 4.0 and later versions of Android system (14 API level), Wi-Fi Direct Wi-Fi Peer-to-Peer (Wi-Fi P2P) extension [10] support was introduced, which, in the basic operation mode, enables peer-to-peer connection for two devices supporting this solution. The standard specification provides for the possibility of creating the so called P2P groups, where one of the clients, P2P GO (Group Owner), is functionally equivalent to the access point (AP) type node from a traditional Wi-Fi operation mode with infrastructure. Thus, frames are transmitted within the given P2P group using GO node (point-to-multipoint topology) at all times. For devices that do not support Wi-Fi Direct functionality, GO node is detected as traditional AP. Therefore, it is possible for P2P group nodes to cooperate with legacy devices. Support for Wi-Fi Direct extension in Android system was described in the official manual for developers in chapter "API Guides, Wi-Fi P2P" [11], whereas results of the experimental tests were published in [12]. Developers of Tapestry application (demonstration [13]) specify the maximum scalability of Wi-Fi Direct solution for 5–6 devices using an image, however there is no information on the Wi-Fi network mode used. The factors limiting functionality of Wi-Fi Direct solution include the necessity to provide visibility between GO nodes in the case of combining P2P groups, or the necessity to provide visibility of GO node for each of network participants, in the case of a network consisting of a single P2P group.

Considering the above, currently there are limited possibilities of using Ad-Hoc mode for multihop transmission for spontaneously compiled MANET networks (Mobile Ad-Hoc NETwork) on devices operating under Android system. Potentially, there is a possibility of using extensions of the system or additional software, developed i.a. within projects using SPAN software (Smart Phone Ad-Hoc Network), with co-financing of the not-for-profit MITRE organization [14, 15]. Although these are only "proof of concept" projects, they are implemented in some of the smart phones. The programs can be downloaded from "Google store" or directly, from the project website [16]. Using Android Manet (AM) Manager and AM Push to Talk applications, a smart phone may turn into a "walkie-talkie" and organize networks in Ad-Hoc mode. An application is also necessary to scan the network environment and deliver address data of the neighbors and "neighbors' neighbors", which will create a graphical book of neighborhood and will allow verification of nodes reachability in multi-hop relations. It is based on AM OLSRd responsible for scanning the neighborhood, whereas AM Visualizer and AM Logger are responsible for the telephone switchboard function.

The aim of another project [17], implemented under the 7th Framework Program, was to ensure multi-hop transmission in a mesh network based on Android devices. The demo version launched on Samsung Galaxy S4 phones enabled live transmission of audio and video streams between the sender and the recipient in the absence of reciprocal and direct radio visibility.

5. SCENARIO OF RESCUE OPERATION, PERFORMANCE OF WI-FI SMART PHONES AD-HOC OPERATION

Let us consider a scenario that can happen every day, e.g.: in the urban area with dense land development, gas explosion occurs in the morning. As a result of the collapse of a large part of the block of at, many residents are trapped. In the area of the disaster, rescue operations are carried out by the fire fighters, medical rescue workers and police officers (approx. 50 persons). Probably, in the building there are survivors. To find them, the rescue services are extinguishing the fire and searching for victims. As a result of the explosion, the mobile telephony radio station mounted in the building and transformer supplying power to the housing estate are damaged, due to which mobile communications is not possible.

Until delivery of specialized communications equipment, the rescue teams use their smart phones operating in 2.4 and 5 GHz band. Ad-Hoc communication is organized by means of Wi-Fi using the available telephone application. It was managed to provide communication in 802.11ac protocol, using MU/MIMO 2×2 technology. Performance tests indicate the available bandwidth of 130 Mb/s. In a few seconds, the scanning program fills the Ad-Hoc network phone book with data concerning the rescue team. A visualization of the Ad-Hoc network appears on the screen, showing names entered by their owners. Relay connections are also possible with one intermediate point in the area with radius of 150 m (Fig. 3). For such preset conditions, we will try to answer the following questions: what is the network performance for simultaneous phone calls, what is the use of radio channel bandwidth, and how many rescuers may be supported at the same time?

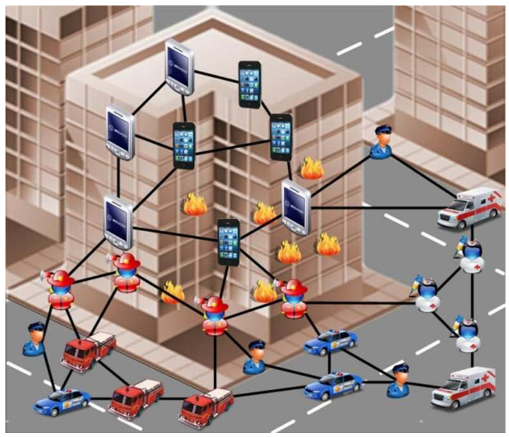

Figure 3: Scenario of rescue operation.

The test was performed using the simulation method for IEEE 802.11ac standard. The assumptions are included in Table 3. The tests did not consider the propagation properties of the radio center and outdoor propagation time was set to 1 us, which is 10 thousand times shorter than the packetization time. Safety issues were not taken into account in the tests.

Table 3: Parameters of the communications system assumed in the simulator.

Band	5 GHz
Channels for 802.11ac	1 channel 80 MHz
Channel throughput 80 MHz	130 Mb/s
Access control	DCF
Tslot, TSIFS, TDIFS, CWMIN	9 us, 16 us, 34 us, 15
Number of stations N1/N2/N3; Range	50/100/150; 300 m
AMR Coder parameters: bitrate, frame length, fps, frame delay	12.2 kb/s, 244 B, 50, 20

The results of network performance, assuming continuous telephone calls in P2P relations for scenarios N1, N2, N3, for a confidence level of 0.95 are as follows:

- Use of channel [%]:1.53; 2.76; 3.81.
- Number of collisions: 13 500; 1 581 000; 1 883 000.
- Max. frame delay [ms]: 3,2; 7,5; 16,2.

As it might have been expected, comparing the size of generated streams and available bandwidth, network usage is very low, whereas the telephony quality very high. Maximum delays (averaged for a given scenario) of 3–16 ms guarantee that the possible jitter will not have a significant impact on deterioration of the telephone call. The tests did not consider the traffic from outside the system. It can be assumed that in the crisis situation described, there will be no data exchange due to the lack of power supply in the area of disaster.

6. CONCLUSION

The use of Ad-Hoc mode has arisen great interest among owners of smart phones. According to authors of this paper, such phone service would very prospective, in particular considering the fact that its use in critical situation is the only method for provision of "any communication". However, Google — the main player on the market — is not currently interested in supporting Ad-Hoc Wi-Fi. The need to adapt 802.11ac to Ad-Hoc mode was reported by the Japanese after the disaster in 2011. The question of whether the Android users will force the support for Ad-Hoc Wi-Fi will be answered in the near future.

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