The Concept of 2-Layer Routing for Wireless 5G Networks and Beyond

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***Abstract*—In this paper, the concept o 2-Layer routing for wireless 5G networks is presented. A new fifth generation of the network along with the platform known as the Internet of Things (IoT) are an upcoming trend not only in the commercial market but also in the research area. The 5G networks and IoT will be part of smart homes, smart cities and every aspect of our lives. They are considered as a promising technology, that interconnects different types of existing networks into one functional network. In this paper, a brief vision of utilization and areas of deployment of 2-Layered network model consisted of Wireless Sensor Network (WSN) and Mobile Ad-Hoc Network (MANET) is described along with communication technologies and protocols needed for the functionality of 2-Layered model. Presented simulations prove that interconnection of MANET network with WSN network provides faster data delivery and higher data rates than traditional WSN network since MANET nodes are able to carry data load from WSN sensors. Therefore, utilization of presented 2-Layered model will be useful in disaster scenarios or data harvesting, when urgent data needs to be delivered quickly.**

***Keywords*—Cognitive Radio, Mobile Ad-Hoc Networks, Flying Ad-Hoc Networks, Concept, 2-Layer network**

I. Introduction

The world is slowly preparing for an upcoming new generation of 5G networks. This also includes a new communication platform known as the Internet of Things (IoT). The main aim of IoT is to make the Internet more and more comprehensive, smart and pervasive. The 5G and IoT are considered a promising technology that interconnects different types of networks. The wide variety of heterogeneous devices will operate in this new generation of the networks under different types of applications [1]. Devices like smartphones, PC, sensors, RFID and different network-enabled devices will collaborate in several domains like smart homes, industrial automation, mobile health care, and smart cities. In order to create such a complex networking system, different types of networks, such as Cellular Networks, Mobile Ad-Hoc Networks (MANET), Wireless Sensor Network (WSN), Vehicular Social Networks (VSN), and Flying Networks (FlyNET) will collaborate in different hierarchies and will create one functional network. This convergence environment with heterogeneous devices enables new Device-to-Device (D2D) communication introduced with 5G, that is also part of IoT environment. This also helps to overcome the limitation of traditional MANET or WSN networks and helps to increase data transfer rate, reduce latency and energy efficiency.

Another area of new generation networks, where convergence and connection of different types of networks are needed are disaster scenarios [2]. Various types of disasters can occur, such as the earthquake, tsunami, volcano, floods or hurricane. To prevent those scenarios, many efforts are underway to recognize and forecast the occurrence of natural disasters. It is very important to react quickly and therefore, the convergence of WSN, MANET or FlyNET could help to achieve this goal. This multilayered network can be also useful when all existing fixed infrastructure is destroyed. The rescue team can response and operate very effectively because of easy and fast deployment, self-organizing and autonomous properties of mentioned networks.

In general, a new generation of networks is an ambitious project that also brings a lot of different problems. All mentioned networks work under different types of technology and network protocols. Therefore, it is very important to specify, how those different networks will collaborate and how network protocols need to be changed to allow effective and fast communication. Another problem arises in the area of data harvesting. A lot of sensors and network-enabled devices will operate in environments like smart cities, smart homes, and mobile health care. Amount of collected data will be huge and besides the high bandwidth, throughput and other network quality parameters (QoS), it is very important to handle those data effectively.

Therefore, in this paper, various ways to interconnect different types of networks into one functional multilayered network that could be deployed in different areas will be presented. The analyze of problems that arise from such interconnection will be also discussed. Simulation and results of the multi-layer network will be leveraged at the end of the paper.

II. Multi-Layer Concept Utilization

In the last couple of years, researchers start exploring the ways to interconnects different types of networks. The latest works show collaboration of different networks in different areas of deployment. The main aim of networks interconnection is to use advantages that those networks offer and overcome their disadvantages. In [3] the authors combine WSN and MANET as an IoT-based scenario.

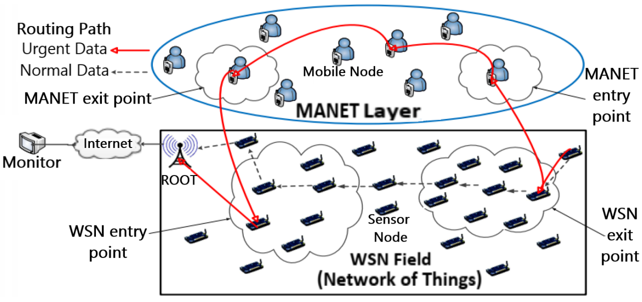

Fig. 1. A simple MANET-WSN convergence scenario in the IoT environment [3].

This combination allows great mobility and flexibility for users and reduces the cost of network deployment. WSN network consists of a huge number of low-cost and easy-deployable sensors. The MANET network consists of wireless devices that are carried mainly by humans. WSN creates a smart interactive environment, but most of the nodes are fixed and operates with low energy resources and low data rates. On the other hand, MANET nodes are mobile with higher processing capabilities, higher data rates, and energy reserves. To send urgent data via WSN itself may take a long time due to low data rates. Instead of routing data through WSN, it is possible to use a gateway to the MANET, where urgent data can be transported faster. Such a scenario is depicted in Fig. 1.

Another similar interconnection of networks is presented in [1]. Authors divided whole architecture into four hierarchies of communication which are considering WSN, MANET, WLAN and/or Internet gateway and the Internet. This IoT network solution can be used in the hospital management system. RFIDs are used to identify patients and WSN sensors are responsible for monitoring the various health conditions. MANET nodes are responsible for data collection and sending them to the nearest Internet gateways. Such a network solution decrease delay of the packet data and decrease energy consumption.

Other works such as [4], [5] combine WSN, ad-hoc networks with unmanned aerial vehicles (UAVs) in disaster application areas. WSN sensors are responsible for monitoring and collecting of data, whereas UAVs can play a role by assuming the load of data delivery from the resource-constrained sensors. Some works such as [6], [7] also combine VSN, Ad-Hoc networks, and WSN networks into IoT scenarios. The main aim of these works is to develop Intelligent Transportation Systems (ITS) that provides car collision avoidance, more secure streets, and the blockage management.

The area of multi-layer networks is still opened a mostly unexplored area and new areas of utilization are constantly growing. The 5G networks and IoT bring new questions and a lot of research is needed in future. Therefore, in the followed section, the concept of 2-Layer Network will be presented and analyzed as IoT scenario.

III. 2-Layer Routing Concept Analyse

The proposed 2-Layer Routing Concept is the interconnection of MANET and WSN network. The first layer consists of low energy wireless sensors. Those sensors could be deployed in different areas such as smart cities to measure important electrical or non-electrical quantities. Sensors are connected into the WSN network, where they operate in an ad-hoc manner. Since sensor nodes in WSN require low-energy consumption and there are also existing resource constraints, they are using IEEE 802.15.4 based link layer, also known as ZigBee. Therefore, sensors are able to communicate over distances up to about 10 meters and with maximum transfer data rates of 250 Kbps. Newest embedded devices are able to communicate with lower transfer rates of 20 and 40 Kbit/s, with the 100 Kbit/s rate being added in the current revision [8]. The IPv6 is selected in the network layer as suitable protocol for the gateway sensor. In order to connect sensor nodes to the Internet, 6LoWPAN protocol is used between the routing layer and MAC layer [9], [10]. If the sensor node is not a gateway, it uses regular WSN routing protocols, such as An Energy-Aware QoS Routing Protocol, proposed by [11].

The second layer consists of MANET nodes. Devices used for this scenario could be smartphones, laptops, PDAs and other similar smart devices. The advantages of MANET nodes over WSN sensor nodes are higher data rates about 72,2 to 150 Mbps, significantly lower resource constraints and also the mobility of nodes. The IEEE 802.11n is used in the link layer, while in the network layer is possible to adopt IPv6 enabled DSR protocol [12].

Inter-layer communication is based on gateways. In WSN layer network exists a small number of the gateway sensor nodes, that are able to communicate with MANET nodes or sends data directly to the Internet/Cloud. This communication is allowed based on 6LoWPAN protocol, that is IPv6 enabled. The sensor gateway for MANET needs to use two protocol stacks, one for communicating with other sensors based on IEEE 802.15.4 and the second for communicating with MANET node based on IEEE 802.11n. It is also useful if both MANET and WSN nodes use UDP transport layer protocol, which is lighter than TCP. At the application layer, protocols are needed to be selected based on low the energy consumption and less complexity such as Efficient XML Interchange (EXI) [13].With EXI protocol it is easier to communicate with cloud web servers with webpage based on XML.

The architecture of 2-Layer network composed of MANET and WSN is depicted in Fig. 2.

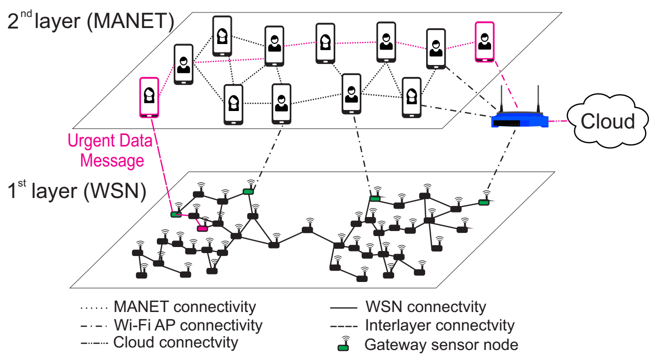

Fig. 2. Proposed 2-Layer network hierarchy comprising Wi-Fi, MANET and Sensor networks.

Both MANET and WSN working independently in the basic state. WSN sensors collect data a sending them to the cloud. In an urgent situation, when urgent data needs to be sent to the cloud, the triggered sensor is looking for the nearest gateway sensor. The gateway sensor is able to intercommunicate with MANET nodes. Urgent data is therefore sent over MANET nodes, where data rates are significantly higher to the cloud. Theoretically, this solution can provide a speedier response to the urgent situation, since data rates and throughput of MANET are higher than in WSN and urgent data is delivered to the cloud with lower delay.

The gateway sensor node could be also used to send data over MANET if regular sensors are too many hops away from the cloud gateway. By this is possible to save energy and overhead of WSN network, that is resulting from transferring of all collected data. To verify above mentioned scenarios, simulation of such communication will be presented in the followed section.

IV. Simulations and Results

A. Simulation scenario

The main focus of the simulations is to show advantages of interconnection of WSN and MANET networks into the functional 2-Layered network over classical WSN network. In the simulation scenario, we are considering one AP gateway to the cloud in the area of 100 meters square. The source node is WSN sensor on the other side of the network from AP. The simulation scenario investigates the situation when the WSN sensor needs to send urgent data to the cloud through classical WSN networks and proposed WSN-MANET network. The simulation scenario considers 200, 300 and 400 WSN sensor nodes in both simulations and 20 MANET nodes in WSN-MANET scenario. Routing protocol based on [11] is used in WSN network simulation, where an ordinary sensor searching for the nearest WSN gateway sensor, which routing data through the other WSN gateway sensors to the AP. In WSN-MANET scenario, the ordinary sensor also searches the nearest WSN gateway sensor, which then sends data to the MANET network. MANET nodes then direct data to the AP based on Dijkstra shortest path algorithm in order to find the path with the highest data rate. The values of data rates on the links were randomly generated with a variation of +/- 50%. The variation of 50% refers to the average human speed of walk (5 km/h) and was set as median value. This variation should increase with increasing node mobility speed. But the impact of link variation on mobility is not a scope of this paper. The data rate of the WSN network was set to the 30 Kbps and data rate of the MANET network was set to 100 Mbps. Specific data rates were chosen based on [8], [14] in order to show differences between traditional MANET/WSN networks and 2-Layered MANET-WSN network model.The amount of data to be sent was set to the 100 Kb. Example of WSN network deployment with 300 sensors and selected routing paths is depicted in Fig. 3. The second example of WSN-MANET scenario with 300 sensors and 20 MANET nodes is depicted in Fig. 4. Radio range of WSN sensors was set to the 10 meters and a radio range of MANET nodes was set to the 40 meters.

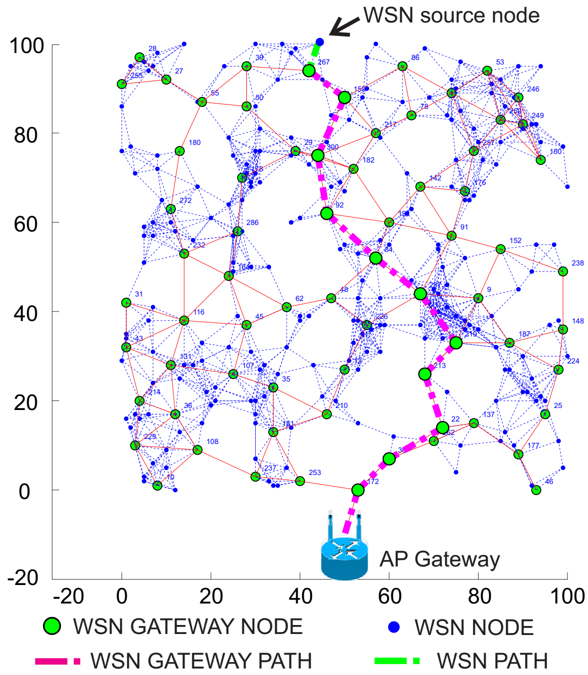

Fig. 3. 1-layer WSN network simulation example (300 WSN nodes).

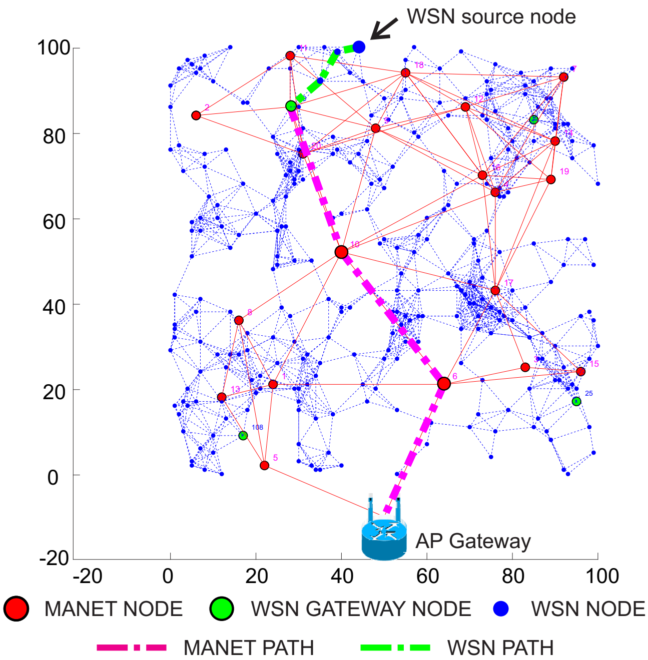

Fig. 4. 2-layer WSN-MANET network simulation example (300 WSN nodes + 20 MANET nodes).

All results provided in graphs are average values calculated from 100 simulation runs for each scenario. All simulations was performed in MATLAB environment.

B. Simulation results

The first result depicted on Fig. 5 shows average time for delivery of 100 Kb data from the source node to AP. In this scenario, the time needed for re-routing data on the node is not considered, we only consider the time needed for data to travel through wireless links. Time to deliver data through the WSN network with 200 sensors was around 39,05 seconds while higher data rates of MANET nodes in WSN-MANET network reduce delivery time to

5,47 seconds. This is approximately 86% improvement in delivery time. In a scenario with 300 nodes delivery time was improved approximately by 77% and in 400 nodes scenario also by 77%.

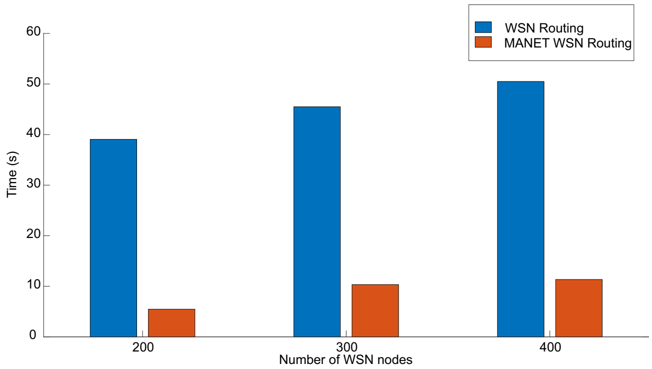

Fig. 5. Average time of 100 Kb data delivery from source node to AP.

The second result in Fig. 6 shows the average number of hops on the path from source node to AP. Results of the average number were rounded to integer values. In WSN scenarios with 200, 300 and 400 nodes, selected paths consisted of 11, 12 and 13 hops. Bigger radio range in WSN-MANET scenario reduces the number of hops in each scenario almost by half to 5, 6 and 8 hops respectively.

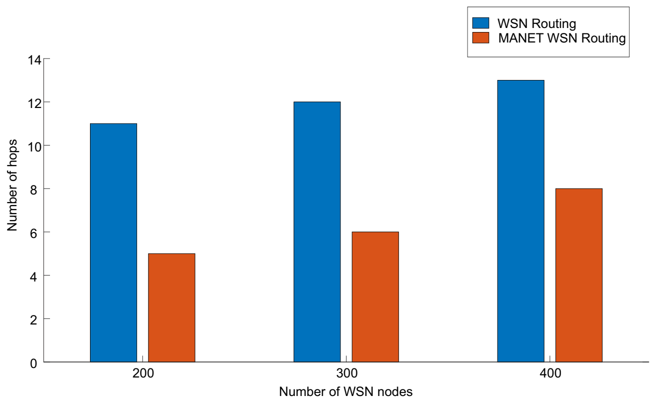

Fig. 6. Average number of hops on the path from source node to AP.

The last results are focused on the average data rate of 100Kb data delivery in Table I. The average number of the data rate in the WSN network for all scenarios was around 31 Kbps, while the average number of the data rate in the WSN-MANET network was around 64 Mbps. Therefore, higher data rate in MANET networks allows urgent data to be transported from source sensor node to the destination with generally higher data rates.

In the WSN-MANET simulation scenarios is possible to notice in Fig. 3, that only 4 WSN gateway nodes were used while in WSN scenarios (Fig. 4) are multiple WSN gateway nodes. If the deployment of MANET nodes in a given area is even, it is possible to choose only one WSN gateway. On the other hand, a number of WSN nodes in the considered area should not be high. This will lead to higher hop count in WSN layer and possibly to a higher level of energy consumption.

TABLE I
AVERAGE DATA RATE (MBPS) OF 100 KB DATA DELIVERY.

	Network	
Number of nodes	*WSN*	*WSN MANET*
200	0,0306	62,631
300	0,0312	63,946
400	0,0338	66,337

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Therefore, the correct WSN Gateway selection along with the impact on energy consumption will be the subject of further future research.

V. Conclusion and Future Work

In this paper, the concept of the 2-Layered network is introduced. Proposed concept consists of a WSN network and MANET network, which can be used in different IoT and 5G scenarios, as well as in various disaster scenarios.

Simulations of such networks interconnection prove that proposed 2-Layered WSN-MANET network model can decrease delivery of urgent data dramatically and also increase data rates on the source path. The connection of the MANET network with WSN network allows WSN sensors node to re-route data load from WSN network to MANET nodes, which are not strictly resource-constrained as WSN nodes. MANET nodes are able to communicate with higher data rates and operate with longer radio range. Redirection of data load to MANET layer could also save energy of resource-constrained WSN sensors need for data delivery process. This corresponds with the 5G network demands of higher data transfer rate, reduced latency, and energy efficiency. In future research, we will focus on the energy aspect of the model in order to evaluate energy consumption differences. A second important step in the future research will be the implementation of the model in the real world with existing WSN sensors and MANET nodes.

Acknowledgment

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