HaLowNet - A WiFi HaLow network-based information system for the provision of multi-sided applications for medical emergency scenarios

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***Abstract*—In this paper, we present the current state of *HaLowNet*, a WiFi HaLow network-based information system for the provision of multi-sided applications. *HaLowNet* is developed for medical emergency scenarios where required IT infrastructure is insufficiently available, which are introduced first. Afterwards, we present the technical network structure of *HaLowNet*, which is conceptualized as a 4-tier layer model. Furthermore, the leader-follower approach used to synchronize the network nodes of *HaLowNet* is described. In complement, the deployment of scenario-specific applications by *HaLowNet* is described. In addition, the scenario-specific multi-sided application *MANVnet* for coordination, documentation, and surveillance of rescue forces in mass casualty incidents, is presented.**

***Index Terms*—*HaLowNet*, *MANVnet*, WiFi HaLow, 802.11 ah, 802.11 b/g/n, decentralized, healthcare, medical emergency scenarios, coordination, documentation, surveillance**

I. Introduction

New challenges arise every day in healthcare, whether inpatient or outpatient care, emergency services, or humanitarian aid operations. Medical information systems play a crucial role in meeting these challenges, supporting diagnostic and treatment processes, and helping make decisions or coordinate operations. Such medical information systems depend on working IT infrastructure, which may fail or collapse, is insufficient, or non-existing in unexpected large-scale emergencies [1]. *Failed or collapsed IT infrastructure*, especially on catastrophic events such as terror attacks or natural disasters, i.e., flood disasters or earthquakes, lead to complex coordination of all involved people. In these types of scenarios, medical professionals often have the problem of caring for a large number of people in need of help in uncontrollable situations [2]. *Insufficient IT infrastructure* is often encountered in scenarios that are highly dynamic or where unpredictable changes frequently occur, i.e., *SARS-CoV-2* pandemic. The acquisition and provision of information and the surveillance of patients are typical challenges in such scenarios [3]. *Non-existing IT infrastructure* in humanitarian aid missions in crisis regions, i.e., *Ebola* virus in Sierra Leone, poses particular challenges for medical professionals. Especially in rural areas, medical software is often not usable due to the missing IT infrastructure [4]. In all of the scenario types presented, the provision of software systems and the corresponding IT infrastructure for medical professionals is inadequate or even non-existent.

In this paper, we present *HaLowNet*, a WiFi HaLow network-based information system for medical applications designed for the deployment in scenarios without working or with limited working IT infrastructure to provide a secure exchange of information.

This paper is structured as follows. Section II presents our approach to a WiFi HaLow network-based information system for deployment and provision of multi-sided medical applications. As an example of a scenario-specific application for the coordination and documentation of mass casualty incidents, *MANVnet* is presented in Section III. Finally, our conclusion is drawn in Section IV.

II. HaLowNet - A WiFi HaLow-based Ad Hoc Network

A. Technical Network Structure

HaLowNet is based on a combination of the IEEE 802.11 ah standard, which enables long-range connections of up to 1 km between network nodes [5] [6], and the IEEE 802.11 b/g/n standard for connections between a network node and a large variety of devices in a range of up to 100m.

HaLowNet is conceptualized as a 4-tier layer model.

1) The *Network Layer* manages the communication between the individual network nodes.
2) The *Synchronization Service Layer* ensures that the data is synchronized between the individual devices.
3) The *Application Server Layer* enables the deployment of one or more Web-based, scenario-specific, medical emergency applications.
4) The *Application Layer* provides scenario-specific multi-sided applications to the different user groups.

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B. Synchronization between the Network Nodes

A *leader-follower* approach is used for synchronization between individual nodes. All requests are executed on the database of a determined node, which is referred to as *leader*. After a write operation on this database, the information is replicated to all *follower* databases. Should a *follower* or sub-network of *followers* lose connection to the *leader*, a new *leader* is determined within that sub-network. The consensus determination process follows that the node with the longest operating time is appointed as the *leader*. If a connection can subsequently be re-established between the two sub-networks, the data sets of the respective *leaders* are merged.

Figure 1 illustrates the synchronization process of *HaLowNet*, which is based on the *leader-follower* approach described above.

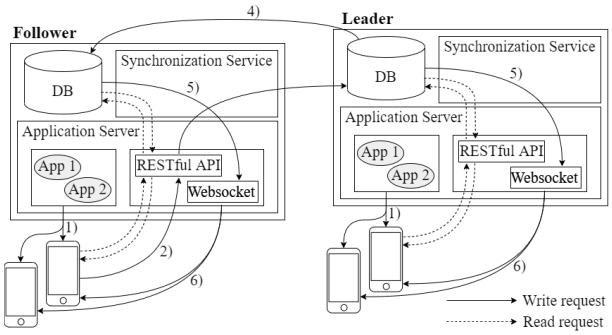

Fig. 1. Synchronization process of *HaLowNet*. 1) Application is delivered from the application server to all devices. 2) Device wants to update information. 3) Request is forwarded by the application server to the *Synchronization Service*, processed, and transmitted to the leader's database. 4) Information are stored and replication ensures that the information in the database is updated by all followers. 5) *Synchronization Service* is informed about the change on all nodes. 6) Change is transmitted to all devices via the Web socket connection.

C. Deployment of multi-sided, scenario-specific applications

The application server, which contains an application repository (app store), enables the deployment of one or more Web-based, scenario-specific, medical emergency applications. Multi-sided applications are provided that offer the best possible scenario-specific presentation of information to different user groups on-site.

III. MANVNET - A MULTI-SIDED APPLICATION FOR MASS CASUALTY INCIDENTS

One possible multi-sided medical emergency applications that *HaLowNet* provides is *MANVnet*, which was developed in a *User-Centered Design* approach [7] in cooperation with *Johanniter Unfall Hilfe e.V.*, a German first aid organization. *MANVnet* is designed for mass casualty incidents (in German: *Massenanfall von Verletzten* - in short, *MANV*) in case that IT infrastructure fails or collapses, to support first responders and rescue forces in coordination, documentation, and surveillance. In such incidents, several tents are usually set up, each accommodating a *HaLowNet* network node. These nodes automatically connect, and then the operation leaders and rescue forces can use the required application directly without time-consuming configuration. The multi-sided application *MANVnet* addresses four user groups. The first user group, operation leaders, must gain and maintain an overview of the current situation. The second user group primarily cares for the patients in the individual treatment tents, while the third group triage the patients, and the fourth group cares about material supply and logistics. *MANVnet* provides for each user group relevant information and supports them in their activities.

Figure 2 presents the dashboard of *MANVnet* used to obtain an overview for the operation leaders.

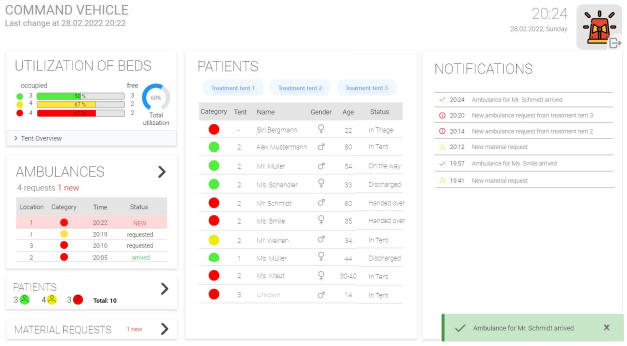

Fig. 2. Screenshot of the dashboard for the operation leaders. On the left, the utilization of the treatment beds is displayed. Below, the information selected for requested ambulances, patients, and material requests are displayed in detail in the center view. On the right-hand side, current notifications are listed.

IV. CONCLUSION

We presented *HaLowNet*, a highly scalable WiFi HaLow network-based information system that provides infrastructure-independent and -integratable multi-sided, medical emergency applications. The combination of two WiFi 802.11 standards makes it possible to bridge large distances of up to 1 km between the different locations (802.11 ah) and still use a variety of devices (802.11 b/g/n). *HaLowNet* automatically synchronizes and documents all information changes during operation. Furthermore, *HaLowNet* provides an integrated application repository (app store), which allows for a user-friendly and easy provision of scenario-specific medical emergency applications, even when no internet connection is available. Finally, we presented *MANVnet*, which can be used as a multi-sided medical emergency application for one of the described scenarios. For all other scenarios, *HaLowNet* is intended to provide corresponding scenario-specific medical emergency applications.

Although *HaLowNet* itself is developed for the medical domain, its concept can be easily transferred to other domains and application areas.

REFERENCES

[1] D. G. Reina, M. Askalani, S. L. Toral, F. Barrero, E. Asimakopoulou, and N. Bessis, *A survey on multihop ad hoc networks for disaster response scenarios*, SAGE Publications, International Journal of Distributed Sensor Networks, vol. 11, no. 10, p. 647037, 2015. (DOI: https://journals.sagepub.com/doi/full/10.1155/2015/647037)

[2] T. Gao, T. Massey, M. Sarrafzadeh, L. Selavo, and M. Welsh, *Participatory user centered design techniques for a large scale ad-hoc health information system*, ACM, Proceedings of the 1st ACM SIGMOBILE international workshop on Systems and networking support for healthcare and assisted living environments, pp. 43–48, 2007.

[3] T. A. Riza and D. Gunawan, *IEEE 802.11 ah Network Challenges Supports Covid-19 Prevention Team*, IEEE, 2020 IEEE 10th International Conference on Electronics Information and Emergency Communication (ICEIEC), pp. 73–76, 2020.

[4] T. Edoh, *Internet of things in emergency medical care and services*, IntechOpen, In: Medical Internet of Things (m-IoT)-Enabling Technologies and Emerging Applications, 2019.

[5] L. Tian, S. Santi, A. Seferagić, J. Lan, and J. Famaey, *Wi-Fi HaLow for the Internet of Things: An up-to-date survey on IEEE 802.11 ah research*, Elsevier, Journal of Network and Computer Applications, p. 103036, 2021.

[6] F. Muteba, K. Djouani, and T. Olwal, *A comparative Survey Study on LPWA IoT Technologies: Design, considerations, challenges and solutions*, Elsevier, Procedia Computer Science, vol. 155, pp. 636–641, 2019.

[7] C. Abras, D. Maloney-Krichmar, and J. Preece, *User-centered design*, Thousand Oaks: Sage Publications, Bainbridge, W. Encyclopedia of Human-Computer Interaction, vol. 37, no. 4, pp. 445–456, 2004.