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A cloud-assisted handover optimization strategy for mobile nodes in industrial wireless networks

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ABSTRACT

Connectivity restoration is an important aspect of the survivability strategies of wireless networks. In industrial wireless networks, especially with mobile nodes, connectivity restoration and maintenance directly determines the overall performance of the network. Handover strategies are research hotspots in this field. However, current common handover strategies have many disadvantages, such as frequent handover requests, latency and the lack of consideration of the network performance. These drawbacks are harmful to IoT (Internet of Things) networks. Although studies on wireless networks have proposed many solutions, the proposed schemes are not intended to meet the demands of industrial wireless applications, where real-time and stable performance are required. Therefore, this paper proposes a novel fixed-path mobile node handover strategy (CAFP), which is assisted by cloud services and an ants-colony algorithm. Our approach uses optimization for industrial wireless node handover sequences, execution and handover schemes in different cases. Compared to other traditional handover strategies, our simulation results show that the CAFP has advantages in terms of handover times, latency and the network's average payload. Additionally, this algorithm can decrease the processing capacity of mobile wireless nodes.

1. Introduction

In recent years, the trend of merging industrial procedures with Information and Communication Technologies (ICT) has become a hot topic of research and applications. The utilization of wireless communication technologies in traditional industrial networks brings flexibility, mobility, agility, efficiency and other advantages [1–4], because wireless equipment has many advantages, including mobility, low costs, lack of need for wires, easy maintenance, flexible deployment, and so on. It is known that connectivity restoration and survivability strategies play a fundamental role in industrial wireless networks. However, mainstream wireless networks are designed to fulfill normal communication requirements, and there are many challenges in the use of these technologies in an industrial environment, such as meeting real-time, stability and security requirements [5–8]. Based on the above factors, many organizations have proposed standards, such as the WirelessHART, ISA100.11a, WIA-PA, IEEE802.15.4e and other industrial wireless networks standards. These standards promote the development and application of Industrial Wireless Networks (IWNs); however, they are mostly semantic-based protocol stacks. More detailed studies are required in the future to deal with the specific and practical requirements of the industry, especially for deployment and specific industrial environments. For this reason, IWN optimization mechanisms and applications for specific industrial environments have become a hotspot of current research and applications, both in China and other countries.

With the proposal of the concept of Industry 4.0, the Industrial Internet of Things (IIOT) and a smart factory [9–13,24], IWNs with a range of advantages have become a key component of the foundation of a new industrial framework. On the one hand, all components within these novel frameworks need to communicate within the same industrial Intranet and environment, and this requirement is not met by traditional wired networks. For network communication, the classical OSI architecture has been extended using the same methods as for Machine to Machine communication (M2M), Cyber-Physical Systems (CPS) and IIOT [25]. For example, components, such as mobile products, robots, working men, Automated Guided Vehicles (AGV) and mobile terminals, are gradually introduced into industrial networks. On the other hand, during wireless communication, as the communication distance increases, the wireless signal strength shows a logarithmically decreasing trend [14], even in a free space. Physical obstacles intensify wireless signal attenuation in industrial fields, resulting in much shorter communication distances and lower connectivity. There is an obvious inevitable contradiction between the limited communication range of mobile nodes and the extensive scope

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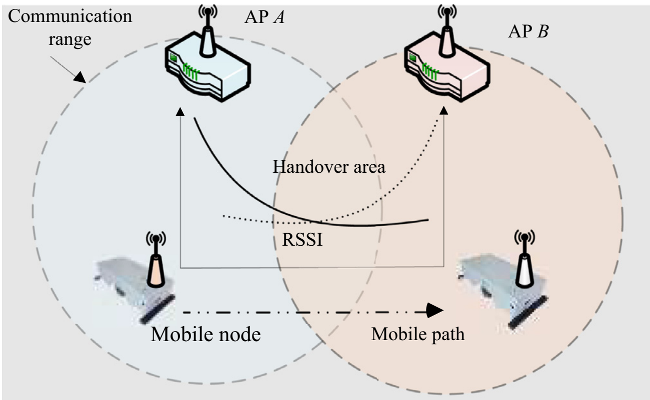

Fig. 1. Industrial wireless mobile node handover diagram.

and space required. To achieve good connectivity and survivability, careful placement of access points, gateways, and base stations (which we call access points) can be an effective solution. A key current problem is determining a method for scheduling handover among moving mobile nodes and access points, while guaranteeing the real-time performance and stability of the entire network. As shown in Fig. 1, as a mobile node moves along a trajectory from left to right, the signal power from access point *A* decreases, and the access point *B*'S Received Signal Strength Indication (RSSI) increases. Therefore, the mobile device must handover communication between *A* and *B* in order to maintain a reliable data link. In this case, a solution to the handover problem among APs in a harsh industrial environment should be placed at the top agenda due to the increasing number of mobile nodes. This is the main motivation of this study.

According to the above comments, it is easy to see that, in industrial mobile networks, connectivity restoration and maintenance directly contributes to the quality of service (QoS). Handover strategies are the most common schemes used for connectivity restoration and maintenance. However, current common handover strategies face challenges, such as frequent handover requests, latency, and the lack of the consideration of the network performance. On the other hand, traditional protocols are difficult to run locally for mobile nodes due to the limitation of capacity. At the same time, a mobile node cannot obtain and process the global information of APs. These challenges and drawbacks hinder the connectivity and survivability of the whole network. In literature [26,27], cloud technologies are used in wireless networks. A cloud-assisted handover optimization strategy for mobile nodes can address these challenges and overcome the disadvantages. So, from this perspective, we propose a handover approach for connectivity and survivability.

The remainder of this paper is organized as follows. In Section 2, we provide a summary of related studies on wireless handover varieties and strategies. In Section 3, the model and related analysis are presented. The architecture and details of the handover algorithm are explored in Section 4. In Section 5, our experimental setup is presented, and its results are compared with other handover schemes. Finally, conclusions and future work directions are provided in Section 6.

2. Related works

In order to ensure a stable and reliable network system in IWNs, it is essential to have an efficient handover mechanism among access points when mobile nodes work in different networks or the same network. An effective mobile handover solution directly determines the performance of mobile nodes, as well as the entire industrial communication system. This is also an important industrial factor of Industry 4.0 and smart factories. Depending on whether mobile nodes belong to the same network, handover may be categorized as either horizontal or vertical. This is similar to civil cellular networks, where mobile phones move among base stations or wireless LAN AP nodes, which use a scheme where access points belonging to the same sub-net have horizontal handover (HH) [15]. In contrast, handover among different sub-nets is named vertical handover [16]. For example, the handovers between 3G and Wi-Fi. Generally, in IWNs, a single network is adopted to maintain low costs and high performance. So, in this paper, we focus on horizontal handover in an industrial environment.

In accordance with the process of handover, the HH can be divided into three steps for its setup: founding, judging, and execution [17]. There are many studies related to the HH in IWNs. In [18,19], the authors present a handover solution based on the RSSI, which executes handover when the mobile node's RSSI drops below a threshold. In harsh industrial domains, the industrial infrastructure has strong impact on the RSSI, resulting in unstable RSSIs in some single positions. So, within a specific time window, the above solution (a fixed threshold) may cause a mobile node to handover between two sub-nets repeatedly, the so-called ping-pong effect. To prevent this effect, in [20] the authors smooth horizontal handover by taking the average RSSI over 100 samples in handover schema. However, in industrial mobile networks, it is generally impossible for a mobile node to remain in the same position to obtain this number of RSSI values. This solution results in high latency, and a decrease in the efficiency of the overall network. Accordingly, in [21], a novel method is proposed for the handover decision based on fuzzy logic using multiple factors including the RSSI, packet loss rate, and Link Quality Indicator (LQI). Experiments are performed in a refinery. Fotouhi [22] uses fuzzy control to consider additional decisions that could trigger handover using the RSSI, LQI, the velocity of the mobile node, and other network factors, and provide related experimental results. The above fuzzy-logic handover schemes have two drawbacks. First, although these algorithms may reduce the handover frequency in industrial environments to some extent, the increased complexity of the decision algorithm performed by the mobile node is difficult for extensive implementation and applications. Second, industrial environments and industrial mobile node performance are not considered in these solutions.

For the real-time requirements of IWNs, the documents in [23] are studied, which are based on the LET and the network latency during the handover process. The results show that the latency of handover is due to three factors: finding the AP, making the handover decision, and performing the handover.

Considering the global network status and topology, combined with the practical requirements of the above-mentioned scenario for the next generation industrial networks and wireless features, our paper proposes a cloud-assisted industrial wireless network handover optimization strategy for mobile nodes. The contributions of this paper are threefold. First, a novel handover framework is presented based on an industrial cloud server. Second, an optimized handover algorithm is designed for IWN mobile nodes, which considers the latency, payloads, the position of the AP, the mobile path, and other factors. Finally, a simulation test and related results are presented.

3. System model

3.1. Problem description

In an industrial environment, an increased number of applications is deployed to obtain high quality of connectivity of IWNs