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Performance analysis of smart cultural heritage protection oriented wireless networks

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HIGHLIGHTS

- We introduce D2D into Smart CH to enhance service provision variety.
- The procedure of flooding based message transmission in D2D of smart CH is analyzed.
- We propose a close-form analysis model for D2D in smart CH.

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ABSTRACT

Currently, Internet of Things (IoT) and wireless sensor network (WSN) techniques are widely used in the cultural heritage protection oriented networks for the environment monitoring, security enhancement issues, and *etc*. However, the low transmission rate and expandability of IoT and WSN limit the application variety of heritage protection networks. In this paper, we introduce the concept of device to device (D2D) communication manner from the 5G mobile network into the smart cultural heritage protection networks to solve the problems of various service requirement and coverage hole due to the location of the heritage. To enable the direct transmission among nodes, flooding based broadcast message transmission is widely utilized, which is used to obtain the prior knowledge that will be further used in the neighbor discovery, routing and other procedures. In this paper, we analyze the performance of flooding based broadcast message reception in D2D mode, where the influence of random time slot selection and message collision are reflected. Based on the random time slot selection manner and the related random process theory, we established the close form expression on the average number of received broadcast messages in the case of D2D without the coordination of central control node. Then, the proposed close form expression is validated through a numerical analysis platform. From the validation results, we find that the introduced closed form expression on the average number of received D2D broadcast packets is consistent with the simulation results.

1. Introduction

Since 2006, wireless sensor networks have been applied in museums and art galleries such as Musée du Louvre and Petit Palais to monitor the environment, to enhance the security details and other advanced data processing techniques [1–6]. However, the low transmission rate of wireless sensor network (WSN) limits service extension and varieties, e.g. the virtual tour, online data analysis and *etc.* cannot be supported by the current wireless sensor network. With the rapid development of mobile Internet and the growing demand for business related Internet of Things, as well as the increasing needs of short range data communication, the concept of device to device (D2D) is introduced into 5G mobile networks to further enhance the system capacity and efficiency, which also provides a new choice for the cultural heritage protection related networks due to its inherent high data rate transmission capability and new WSN like transmission feature. By Introducing D2D into a cellular system, users' performance such as data

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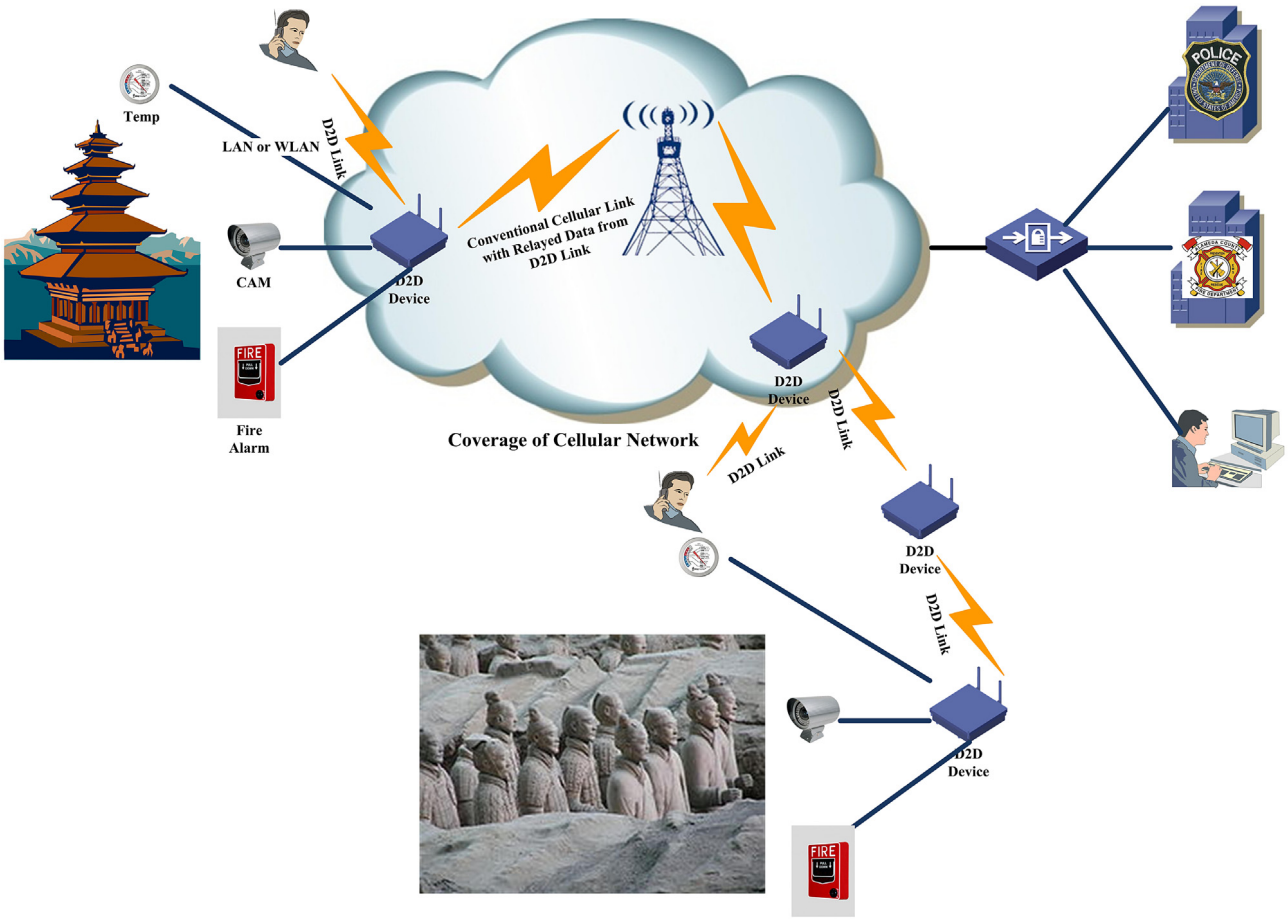

Fig. 1. Illustration on the application of D2D communication manner in the cultural heritage protection.

rate and quality of experience is enhanced. As a novel high-speed communication manner in cellular networks, data can be transmitted and received directly on the pre-designated resources among D2D users without the coordination of base stations, which can alleviate the load of base stations and solve the problem of coverage hole in the conventional cellular networks. The system capacity can be enhanced by appropriate radio resource management and interference mitigation methods [7–15]. However, the introduction of D2D will raise higher requirements on the user's capabilities, e.g. the works related to routing, resource management should be done by users themselves other than base stations especially in the case of coverage hole. Fig. 1 shows an example of D2D communication manner adopted in the smart cultural heritage protection oriented wireless networks, where the D2D communication manner can be used to solve the problem of coverage hole and data rate enhancement, e.g. with the support of mobile communication networks various service such as temperature monitoring, real-time alerts, high-speed video monitoring and visual on-line tour can be supported.

At present, most D2D related researches focus on the issues of resource allocation, interference coordination, power control and etc. In [8–10], the resource management issues related to D2D are addressed. The resource allocation issue for inter-cell scenarios where a D2D link is located in the overlapping area of two neighboring cells is investigated in [8]. [9,10] deal with the resource management issues with multi-hop transmission. J. Wang and et al. suggest preferentially selecting the good quality D2D links with high achievable data rates, which induces multi-phase transmissions. By designing three gradually in-depth rules to set the threshold, according to the achievable data rates of all D2D links within a cluster, the three D2D relay schemes are selected accordingly [11]. In [12], authors address a resource allocation problem through integrating a pair of device-to-device terminals into a time division duplex cellular network. By utilizing an incremental relay transmission scheme, the D2D users are coordinated with other cellular users in the uplink. [16] focuses on the problem of retransmissions, which analyzed the relationship between resource cost and the number of relay nodes. Finally, a closed-form probability density function for an optimal number of D2D relay nodes is derived. From the above we found that most D2D related researches focus on the scene of base station assisted D2D communication, and less is done in the case of coverage hole of base station. In the case of D2D users are outside the coverage of base station, users need to discover the neighbor nodes by flooding based broadcast message, which will be the basis for future routing and other procedures. To avoid the resource waste induced by flooding based broadcast message transmission (uncoordinated transmission with collisions), optimized system parameter configuration is required, which may reduce the number of retransmissions and latency for the neighbor discovery procedure. However, most broadcast packet transmission related parameter configuration comes from the simulation other than prior calculation, due to the lack of unified and effective mathematical expression to describe flooding based broadcast packet transmission performance with collisions.

In order to solve the above problem, the random time slot selection outcomes of flooding based broadcast message transmission are analyzed in this paper, and then a close form expression on the broadcast message transmission performance

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