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Machine-to-machine communications: Technologies and challenges

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ABSTRACT

Machine-to-machine (M2M) communications emerge to autonomously operate to link interactions between Internet cyber world and physical systems. We present the technological scenario of M2M communications consisting of wireless infrastructure to cloud, and machine swarm of tremendous devices. Related technologies toward practical realization are explored to complete fundamental understanding and engineering knowledge of this new communication and networking technology front.

1. Introduction

Following tremendous deployment of Internet and mobile communications, Internet of Things (IoTs) and cyber–physical systems (CPS) emerge as technologies to combine information communication technology (ICT) with our daily life [1–3]. By deploying great amount of machines that are typically wireless devices, such as sensors, we expect to advance human being's life in a significant way. In particular, autonomous communications among machines of wireless communication capability creates a new frontier of wireless communications and networks [4,5]. In this paper, we will survey some technological milestones and research opportunities toward achieving machine-to-machine (M2M) wireless communication ultimately serving human beings.

Fig. 1 delineates the fundamental network architecture of cloud-based M2M communications, consisting of cloud, infrastructure, and machine swarm (or machine oceans, to stand for a great amount of machines). Networking in the cloud, typically done by high-speed wired/optical networking mechanism, connects data centers, servers for applications and services, and gateways to/from the cloud. The infrastructure interconnects cloud and machine swarm/ocean, which can be wired or wireless. In this paper, we focus on wireless infrastructure, which allows flexibility and mobility to enable M2M applications and services. For potentially wide geographical range and diversity of deployment, cellular systems play the key role in (wireless) infrastructure. We therefore introduce 3GPP type of systems supporting M2M [5–7] in details. The data aggregators (DAs) are transmitting/receiving, collecting, or fusing information between infrastructure and machine swarm, which can be considered as the access points to

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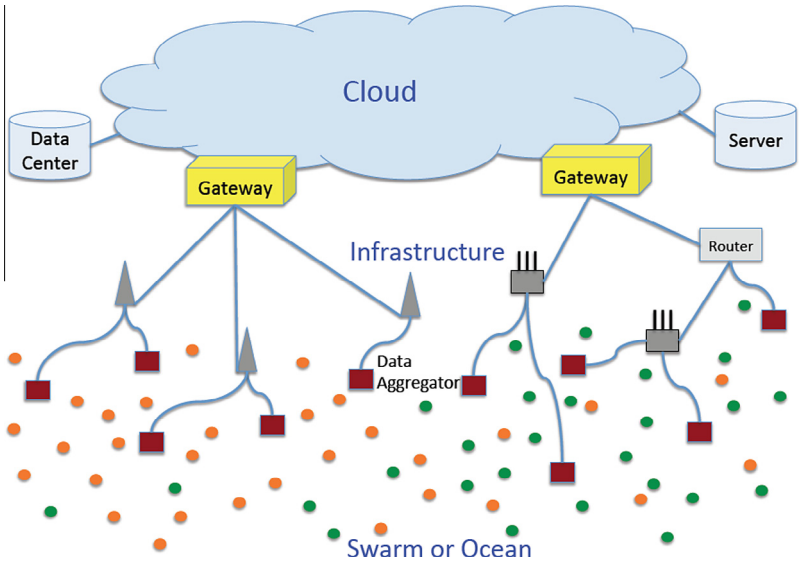

Fig. 1. Cloud-based M2M communications.

infrastructure networks. Finally, the number of machines can go up to trillions according to various reports. Such a huge number of wireless devices form machine swarm or machine ocean, and create a new dimensional technology challenge in wireless communications and networks, after the triumphs of wireless personal communications for billions of handsets in past two decades. It also suggests potential challenges in deployment, operation, and security and privacy.

Consequently, the organization of this paper surveys and highlights technology for M2M wireless communications as follows. Section 2 is dedicated to wireless infrastructure. Section 3 summarizes technology to achieve efficient communications in machine swarm/ocean. Various issues in deployment, operation, and security and privacy, are explored in Section 4.

2. Wireless infrastructure

To practice M2M communications, few realizations of M2M communications have been proposed, such as leveraging Bluetooth (IEEE 802.15.1), Zigbee (IEEE 802.15.4), or WiFi (IEEE 802.11b) technologies. However, there is still no consensus on the network architecture for M2M communications over these wireless technologies. Considering that the ultimate goal of M2M communications is to construct comprehensive connections among all machines distributed over an extensive coverage area, the network architecture of M2M communications leveraging these wireless technologies can generally be considered as the heterogeneous mobile ad hoc network (HetMANET), and faces similar challenges that can be encountered in the HetMANET. Although a considerable amount of research has provided solutions for the HetMANET (connections, routing, congestion control, energy-efficient transmission, etc.), it is still not clear whether these sophisticated solutions can be applied to M2M communications due to constraints on the hardware complexity of a MTC device. Because of these potential concerns, scenarios defined by 3GPP thus emerge as the most promising solution to enable wireless infrastructure of M2M communications [5,8,9].

2.1. Ubiquitous connections via 3GPP heterogeneous network (HetNet) architecture

To provide ubiquitous wireless connections for user equipments (UEs) of human-to-human (H2H) communications in indoor and outdoor environments, a special network architecture known as heterogeneous network (HetNet) is introduced by 3GPP LTE-Advanced [10–12]. In the HetNet, in addition to conventional macrocells formed by evolved universal terrestrial radio access (E-UTRA) NodeBs (eNBs), there are picocells formed by small transmission power eNBs deployed underlay macrocells to share traffic loads of macrocells, femtocells formed by HeNBs deployed underlay macrocells to enhance signal strength and coverage in the indoor environment, and relay nodes (RNs) deployed in coverage edges of macrocells. The 3GPP infrastructure provides higher layers connections among all stations of eNBs, HeNBs, and RNs. Although, in the HetNet, there is potential interference between small cells in the air interface (of picocells, femtocells, and RNs) and macrocells, such interference can be effectively mitigated by applying recent solutions ([14] for picocells, [13–17] for femtocells, and [18,19] for RNs). As a consequence, by attaching to these stations, ubiquitous connections among all machines can be provided. In 3GPP, a machine is referred to a machine-type communication (MTC) device. An illustration of the M2M communications in 3GPP is shown in Fig. X. By the 3GPP infrastructure, a secure, energy efficient, reliable and mobility-empowered connection at the same level of common UEs can be provided for M2M communications.

Although 3GPP provides all these technical merits, it does not suggest a successful practice of M2M communica-