Future Communication Trends toward Internet of Things Services and Applications





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As networks have continued to gain popularity throughout the 1980s and well into today, communication technologies have taken a critical number of major twists and turns, with a wide variety of wireless technologies, protocols, services, and configurations developed and deployed. There have been murmurs of network functions virtualization and software-defined networking in the past 10 years, but these technologies have been caught in the spotlight of attention in recent years. Today, network functions (e.g., firewalls) reside in the cloud to increase network agility and scalability while also enabling effective use of network resources. Similarly, mobility has advanced from an employee's former luxury to today's business necessity. Mobile devices and smartphones have not only transformed personal communications but also increased business productivity and revolutionized society. Consonantly, the Internet of Things (IoT) has been dominating the technological landscape, from autonomous connected vehicles to wearable devices.

Communication is pivotal to IoT. Networking technologies allow IoT devices to communicate with other devices, applications, and services. There is a broad range of connectivity technologies available for system engineers and developers building IoT products and systems. Depending on the application, and requirements such as range, data features, power demands, intermittent connectivity, interoperability, and security will mandate the choice of one or more technologies. With the significant development of intelligent communication technology, IoT is expected to play a major role in several application domains such as e-health, intelligent transportation systems, and smart cities. This feature topic focuses on the key challenges and considerations that are related to communications within IoT, including power usage, intermittent connectivity, interoperability, orchestration, and security.

In this *Wireless Communications Magazine* Feature Topic (FT), the Guest Editors invited researchers from academia and practitioners from industry to submit their innovative research on future communication architectures and protocols to support IoT services and applications. This FT aims at addressing advances in research on future communication and networking technologies, covering topics ranging from enabling technologies to emerging applications and industrial experiences. After rigorous review, 13 papers were selected covering different applications and services of Internet of Things considering future communication trends.

High mobility in vehicle-to-vehicle communications provides better coverage and quick access to neighboring nodes. However, the quality of service (QoS) can easily be degraded, especially in multimedia transmission due to the fluctuation in the wireless channels. Sodhro *et al.*, in "Quality of Service Optimization in IoT Driven Intelligent Transportation System" develop a QoS-aware algorithm that supports multimedia transmission in V2V communication over an IoT-driven edge computing network while maintaining energy efficiency, reliability, coverage, and service availability. The performance of the algorithm has been validated by real-time datasets for the use case of medical healthcare where ambulances have to communicate patients' videos among each other and other parties such as hospitals, physicians, and medical centers.

Collecting vehicular speed is an effective method for traffic monitoring and optimal route planning. However, users' privacy is a major concern that can limit collecting this information; also, traffic monitoring is difficult in the self-organized network where there is no central node that collects and analyzes the data. Zhu *et al.*, in "Traffic Monitoring in Self-Organizing VANETs: A Privacy-Preserving Mechanism for Speed Collection and Analysis," propose a privacy-preserving traffic monitoring solution for vehicular ad hoc networks that incorporates homomorphic encryption, data perturbation, and super-increasing sequence. The security analysis results show that the solution can preserve users' privacy as well as prevent collision attacks. Experimental results confirm the efficiency of the solution in terms of computation and communication costs.

The healthcare system is benefiting from the continuous emerging domain of IoT since it leverages the opportunities offered by the ubiquitous and pervasive presence of connected objects and smart services. This attitude has given rise to the concept of eHealth, thus enabling new approaches and solutions for healthcare. In this framework, Bisio *et al.*, in "When eHealth Meets IoT: A Smart Wireless System for Post-Stroke Home Rehabilitation," propose SmartPants, an IoT-based wireless system specifically designed for the remote rehabilitation of lower limbs in post-stroke patients. The platform consists of multiple nodes used to monitor physical therapy and a software platform that provides real-time feedback on the execution by recognizing the type of exercise currently being performed by the patient. Their experimental results, evaluated through appropriate metrics, show that the proposed movement recognition algorithm provides very good results in terms of classification performance.

Different from traditional centralized systems, a distributed blocked-based security protection system is proposed by Wang

et al. in "Distributed Security Architecture Based on Blockchain for Connected Health: Architecture, Challenges, and Approaches." In particular, they exploit the smart contract as an intelligent protocol in blockchain technology to automatically achieve system confidentiality, integrity, and authenticity. The research challenges related to the security and privacy issues in the proposed system are then analyzed, followed by potential solutions. Finally, a security performance analysis and simulations are carried out to further validate and evaluate the security and effectiveness of the proposed system.

Considering the high traffic demand generated by IoT devices in mobile access networks, drone base stations (DBSs) can be flexibly deployed to hotspot areas as relays between the access nodes and IoT devices. However, the limited batteries of DBSs can degrade their backhaul capability and hence impact the throughput of the IoT devices. Ansari *et al*, in "SoarNet," propose a Free Space Optics as Backhaul and Energizer for Drone-assisted Networking (SoarNet) architecture, where a free space optics (FSO) link serves as the backhaul link between a DBS and its access node. The FSO link is a laser beam that carries both data and energy, which can simultaneously receive high-speed data streams and energy. Finally, they discuss how the DBS placement and user association impact the network performance.

The detection of vehicle presence in parking slots is a fundamental part of smart parking systems. The problem is tackled by IoT devices composed of magnetic or infrared sensors, which usually are either magnetic or infrared. The sensor is continuously sampled to determine the slot status (available or occupied) then sends the status to a central collection by means of wireless technology. Nevertheless, cost and power consumption are still an issue. Solic *et al*., in "Proof of Presence: Novel Vehicle Detection System," propose a low-power and cost-effective approach based on two novel vehicle presence detectors, one battery powered and based on 868 MHz LoRa technology, and the other solar-cell powered and adopting battery assisted passive (BAP) 866 MHz UHF RFID technology. The obtained results demonstrate the appropriateness of the proposed approach since the same functionalities of conventional devices at a lower cost and lower consumption are reached.

Route planning in vehicular networks based on the efficient collection of real-time data can effectively mitigate traffic congestion problems in urban areas. However, dynamic route replanning and effective sharing mechanisms based on real-time data are still challenging problems. Ahmed *et al*., in "Real-Time Route Planning and Data Dissemination for Urban Scenarios Using Internet of Things," describe route planning and data dissemination in real time using the Internet of Things paradigm. This objective is achieved by a novel data dissemination technique for information sharing among the roadside units in a hybrid VANET intelligent transportation system (Hybrid-VITS). Hybrid-VITS comprises VANETs, vehicular traffic servers, and a 5G-based cellular system of public transportation. By considering the traffic congestion in urban areas, the optimal path is calculated to replan routes based on the k shortest path algorithm, and a load balancing technique is adopted to avoid further congestion.

Precision agriculture is recognized as one sustainable, eco-friendly, and profitable mode to improve agriculture yields and quality, and will ultimately come true with the further implementation of IoT techniques in agriculture. To facilitate the implementation, Ruan *et al*., in "Agriculture IoT: Emerging Trends, Cooperation Networks, and Outlook," make a visualization review of the agriculture IoT literature in the last decade, using records of 3168 documents and their 100,205 references in the Web of Science. The dynamics of research fronts and intellectual bases bring out emerging trends on both applied IoT techniques and related topics in agriculture. Based on the number of contributions in the cooperation networks, outstanding countries, institutions, and authors are detected. Moreover, influential studies and scholars are recognized from the citation networks, indicating research hotspots and trends in the agriculture IoT literature from 2009 to 2018. Through the review, they also propose future recommendations, including the construction of agriculture IoT infrastructures, data security and data sharing, sustainable energy solutions, economic analysis and operation management in agriculture IoT, and IoT-based agriculture financing and e-business modes. These results are helpful for scholars and practitioners to make further efforts on achieving IoT based precision agriculture.

The intelligent IoT system ensures scalability in challenging or hostile environments. With the emergence of the software defined networking (SDN) domain offering programming ability of the control plane, many of these challenges seemed surmountable. Mishra *et al*., in "Software Defined IoT Systems: Properties, State of the Art, and Future Research," present a synergized overview of the challenges faced by the traditional domain and how they can be overcome by the upcoming domain of SDN-IoT. The authors present a thorough analysis of the practical adoption and feasibility of the solution in a real-time environment. They examine the state of the art and highlight some of the key open points in the domain based on shortcomings of the current state of SDN-IoT, which can be taken up for future research.

Internet of AVs (IoAV) technology utilizes advanced information and communication technologies to enhance the operational capabilities the vehicles, which in turn generate vast amounts of data and information to be exchanged between autonomous vehicles (AVs). Since the wireless connectivity between the AVs is constantly expanding, the transmission of data is expected to pose several challenges to conventional wireless networks, including resource utilization, network optimization, and quality of service. To overcome these challenges, Kaur *et al*., in "SDN-Based Internet of Autonomous Vehicles: An Energy-Efficient Approach for Controller Placement," propose an architecture based on SDN named SD-IoAV for the integration of SDN with IoAV composed of multiple SDN controllers across the widely dispersed SDN domains that manage the underlying communications. They develop a heuristic technique to solve the controller placement problem (CPP) of SDN that achieves energy minimization and load balancing under latency restrictions. The simulation results show that the proposed scheme attains higher energy savings and better load capacity management compared to existing techniques.

Fog and mobile edge computing spread communication, storage, and computing resources all over the wireless access network, hence providing greater resource and service access to resource-limited and energy-limited wireless and mobile devices such as smart vehicles. Al Ridhawi *et al*., in "Comparing Fog Solutions for Energy Efficiency in Wireless Networks: Challenges and Opportunities," envision a smart city solution that considers collaboration among vehicular and mobile nodes to provide a more energy-efficient service delivery mechanism. Different solutions are examined that consider cloud and fog entities used to deliver continuous and stable simple and complex services for both current and future vehicular node service requests. One of the considered energy-efficient solutions forms clusters of both vehicular and mobile nodes according to their service, energy, and movement characteristics. They compare four different solutions using simulation tests to identify those solutions with adequate service delivery guarantees and energy consumption.

Energy management in green Internet of Vehicles (IoV) systems is a challenging problem that recently has been focused on optimizing the energy requirements of battery-enabled roadside units (RSUs) and electric vehicles (EVs). However, these two issues are always resolved separately, which shows the need for a comprehensive investigation of integrating energy management between battery-enabled RSUs and EVs. Wang *et al.*, in "Future Communications and Energy Management in Internet of Vehicles: Toward Intelligent Energy Harvesting," propose an intelligent energy harvesting framework based on vehicle-to-infrastructure (V2I) communications in green IoV communication systems. Specifically, they develop a three-stage Stackelberg game to maximize the utilities of both RSUs and EVs in V2I communications. Performance evaluation has been conducted based on a real-world trajectory to show the effectiveness of the scheme.

In order to optimize the strategy of resource assignment, the tasks of assigning the limited computational resources in MEC servers and resolving the high latency problem in cloud servers have attracted growing interest from researchers. Wan *et al.*, in "Task-Driven Resource Assignment in Mobile-Edge Computing Exploiting Evolutionary Computation," propose a joint optimization paradigm for task-driven resource assignment based on evolutionary computation considering both power consumption and computation/communication delay simultaneously. The MEC framework consists of MEC servers, mobile devices, and cloud servers, and offloads the computational resources to the edge of end users. Additionally, they introduce and analyze three typical task-driven cases, which are a server-determined condition, server-flexible condition, and server-uncertain condition. Finally, they give the existing technical challenges and discuss the open research issues.

Biographies

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Sohail Jabbar received his Ph.D. degree from Bahria University, Islamabad, Pakistan. Currently, he is a postdoctoral fellow with the CfACS IoT Lab, Manchester Metropolitan University. He has served at different academic and managerial positions at National Textile University, COMSATS University Islamabad, and Bahria University in Pakistan. He has authored two book chapters and published more than 100 research articles. He has been engaged in many national and international level projects. He has been a Guest Editor of Special Issues in leading journals in his domain. He is performing collaborative research with renowned research centers and institutes around the globe on various issues in the domains of IoT, WSN, and Blockchain.

Mohamed Abdallah received his M.Sc. and Ph.D. degrees from the University of Maryland at College Park in 2001 and 2006, respectively. He is currently an associate professor in the Information and Computing Technology Division, College of Science and Engineering, Hamad Bin Khalifa University. His research interests include wireless communication, security, and smart grid. He is the author of more than 140 publications. He is currently serving on the Editorial Boards of *IEEE Transactions on Communications* and the *IEEE Open Journal of the IEEE Communication Society*.

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