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ScienceDirect

Procedia Computer Science 60 (2015) 216 – 225

Procedia Computer Science

19th International Conference on Knowledge-Based and Intelligent Information and Engineering Systems

Cognitive Network Framework for Heterogeneous Wireless Networks

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Abstract

The Internet is used by more than two billion customers around the world and is expected to serve as a global platform for interconnecting cyber-physical objects that form the Internet of Things (IoT). Within the next decade, traffic demands are expected to increase a thousand-fold. This challenge can be addressed by introducing and expanding heterogeneous wireless technologies, which provide higher network capacity, wider coverage and higher quality of service (QoS). However, the heterogeneity and complexity of these networks are a major challenge for traditional control and management systems. Therefore, there is a need for self-manageable and self-configurable networks that support the data produced by the different IoT devices and provide opportunities for data analytics. In this work, a cognitive network framework is proposed, in which the network protocol stack is integrated with a semantic system. The proposed framework provides the bases for building smart networks that observe data from different layers in the network protocol stack and represents it in a hierarchical structure in a knowledge base. The framework employs an ontology that provides an abstraction model for the different heterogeneous wireless devices. The ontology determines the relationships between technology-dependent parameters in the network protocol stack and enables, through the use of inferences, the utilization of the observed data from the network. The use of a cognitive network framework with the network protocol stack allows adding ontologies to describe the data, a solution which could solve the problem of analysing, searching or visualising data.

Peer-review under responsibility of KES International

Keywords: semantics; ontologies; heterogeneous networks; next-generation networks; IoT

1. Introduction

In the 2014 annual digital universe study, International Data Corporation (IDC) announced that in 2013, only 22% of data produced by the Internet was eligible for analysis (the data is useful if it is characterised or tagged)[1]; furthermore, only 5% of this eligible data are well tagged and could be analysed. The Internet of Things (IoT) is an

Peer-review under responsibility of KES International
doi:10.1016/j.procs.2015.08.121

extension of the existing Internet architecture and serves as a global platform of interconnected physical objects or 'things' to enable a new way of working, interacting and living. IoT applications include many fields such as industrial and urban sensor networks. The number of physical things in the world already far outnumbers the number of people. This creates new challenges in terms of integrating IoT with the Internet as the Internet architecture needs to serve much more traffic due to the new demands introduced by the connected physical things. The integration of the physical world requires self-configured networks in which the physical devices take decisions without the assistance of human beings.

Wireless communication plays an essential role in interconnecting the physical entities and provides an infrastructure for the future of the Internet. However, wireless communication suffers from the lack of available radio spectrum, limited capacity and interference. During the past few years, the traffic demands in mobile wireless networks have witnessed enormous growth due to online games, video conferences and online TV, which will overload the current capacity of wireless networks.

In order to meet the massive growth in traffic demands, network operators need to add more wireless nodes or provide new spectrums. Utilizing more nodes with multiple heterogeneous wireless technologies is of the means of perusing more dense networks and providing more spectrums. One promising wireless technology is long term evolution (LTE) [2], which is an evolution of the 3G standard and could provide a high transmission rate up to 326.4 Mbps with a wide coverage. Many mobile operators are adopting LTE networks to provide high-speed Internet service to their clients. However, LTE could suffer from poor performance at the edge of the cells, inside buildings or in crowded areas, which causes high uplink traffic. Another wireless technology is the IEEE 802.11, commonly known as Wi-Fi [3]; it provides low-cost, convenient and high transmitting speed technology. Wi-Fi has already been deployed in many hotspots, including airports, libraries, coffee houses and hotels. Compared to LTE, Wi-Fi uses unlicensed frequency bands, which means it is not necessary to pay for bandwidth; however, this attribute also increases the possibility of interfering with other neighbouring networks. Wi-Fi provides better indoor coverage, and the chipset price for Wi-Fi is dropping continuously, making it an economical networking option which is being included in more and more devices. Wi-Fi offers a data rate up to 780 Mbps in the new IEE802.ac, and the bandwidth is device-to-device transmission. Thus, each device utilises all the available bandwidth to transmit the incoming traffic by using carrier sense multiple access with collision avoidance (CSMA/CA) as a medium access control. However, Wi-Fi networks suffer from the lack of available spectrum, interference and collision.

In order to face the surging data requirements, it is necessary to effectively utilise the existing wireless technology, such as LTE and Wi-Fi, to provide greater capacity and better service to the end user. The heterogeneity of the wireless technologies, standards and data formats make the interoperability of such a complex system a very challenging problem. In this work, a new cognitive framework to model the heterogeneous wireless network is proposed. The aim of the proposed cognitive network is to provide a general framework for the heterogeneous wireless network that is easily expandable to add new wireless technologies and new sets of rules to reuse the available knowledge in optimising the wireless network. The framework employs ontologies to provide an abstract model for the components of heterogeneous networks. In addition, a set of rules is developed to be utilised by the inference engine to allow different types of reasoning on the knowledge base. The proposed framework employs ontology to create relations among the technology-dependant features, and then an inference engine utilises the knowledge to infer the appropriate action based on a set of predefined rules. The cognitive framework is connected with each layer in the ttransmission Control Protocol/Internet Protocol (TCP/IP) protocol stack and observes parameters from each layer. Therefore, it is possible to describe low-level networks operations, like routeing, managing heterogeneous transmission technology or characterising application layer data. Ontologies enable networks to enrich and unlock data through exploring the different relationships between different data. The proposed framework has the potential to be extended for describing and storing the data such that it is interpretable by computerised machines by using reasoning system on the knowledge base.

2. 2. Related Work

This section reviews advanced approaches to employing ontologies and knowledge engineering in wireless networks. It first highlights the use of semantic technologies and ontologies in networking and wireless communication. Then it review the methods to manage heterogeneous wireless networks.