An optimal resource allocation scheme for Fog based P2P IoT Network

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Abstract

The concept of IoT kindles numerous prospects to the heterogeneous IoT devices to blend within a network of cohesive intelligent systems. As the number of smart devices grows rapidly, edge computing is becoming a necessity to support the decentralized and distributed computing at the edge of the network to lessen the dependency on the core of the network. Moreover, the envision of Fog computing has also uncovered the possibility of providing edge computing to the end user in order to ensure better QoS. However, a context-aware optimal resource allocation scheme for P2P IoT network is crucial to achieve the application specific demand of the IoT devices with dynamic QoS requirements. Therefore, this paper addresses the context-aware and optimal resource allocation scheme for the decentralized hybrid P2P IoT network to achieve the stringent QoS requirement of the P2P IoT based applications. The simulation result shows a higher utility gain due to the proposed optimal resource allocation scheme in one-to-many peer association.

1. Introduction

The notion of IoT endorses a diverse range of wireless network systems, services and applications to bled within a network. In addition, the future network motivates the application of diverse range of short and long range communication medium. The futuristic networking paradigm such as IoT along with the opportunistic network demand for the support of dynamic and robust short and long range communication medium. At present, based on the hardware and communication capabilities, the IoT device are categorized into two distinct classifications such as high-end and low-end IoT devices. The resourceful high-end IoT devices have more processing power, memory and storage than the resource constrained and low-end IoT devices. Thus, the high-end IoT devices are able to initiate cooperation with each other to provide the edge computing experience to the end user in order to perform the basic functionalities of applications at the edge of the network. Such kind of endeavor is supported by the centralized solution at the edge of the network which is supported by the Fog computing paradigm [2]. The Fog components reside at the edge of the network so that it can monitor the mobility of the IoT devices, in particular location awareness and low latency for fog based services in IoT [4]. As a result, the cooperation between the edge components like IoT devices follow the semi-distributed or hybrid architecture like peer to peer networking model to sustain the context awareness capability for the growing demand of IoT applications rather than the traditional centralized approach [3]. However, the resource allocation still poses a challenge to enable edge computing to the end IoT devices so that they can share their own available resources to perform tasks distributed. So, the main contribution of this paper is to propose an optimal network resource allocation scheme for different P2P IoT application with one-sided matching game which fulfills the application specific QoS requirements.

In [1] the authors propose an incentive mechanism for such kind of peer to peer network where the incentive mechanism design helps to prevent the "free riding problem" in P2P network. In addition, the Stackelberg game approach follows the traditional hierarchical game to solve the strategic peering for different mobile P2P entities. In [5] the authors proposed a distributed optimization protocol derived from a consensus algorithm for resource allocation and management in IoT. Their proposed solution can fulfill the resource allocation requirement of homogeneous IoT nodes which is also vigorous against any node failure during runtime. In [8] the authors have focused on the pervasive usage of the mobile devices according to the user requirement of running the same computation task that they use in more powerful devices. In addition, the authors have used the cyber foraging techniques where non-mobile devices act as surrogate and the mobile devices can utilize these surrogate devices to run the programs that are not compatible with the traditional mobile device configuration.

2. System Model

In Fig.1, the system model represents a P2P IoT network composed of a set of n number of heterogeneous OFDM IoT devices $M = \{m_1, m_2, .., m_n\}$ in Fog environment. Moreover, different IoT nodes are connected to the Fog infrastructure, more specifically Fog network coordinator in order to communicate with each other remotely. In addition, the network coordinator in Fog coordinates the mobility of the IoT devices and has the complete network information. The network coordinator also communicates with other Fog network coordinator in case of the mobile IoT devices move from one Fog location to the other Fog location.

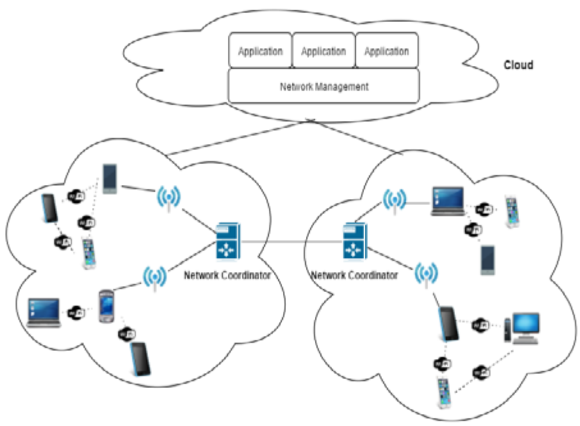

Figure 1 Fog based P2P IoT network System Model

The IoT devices in the set M establishes peer to peer communication with each other where the peer association is denoted as μ. The IoT devices have individual utility based preference list $P = \{p_1, p_2, .., p_n\}$ where the size of the preference list is $2n-1$. The link capacity of each peer association μ is,

$$L(\mu, \rho, n) = n\, log_2(1 + \frac{\rho}{n}) \quad (1)$$

In (1), ρ is the signal-to-noise ratio (SNR) and n is the number of uncorrelated sub channels. The end-to-end delay is denoted as,

$$d_{end}(k) = k\, [d_{trans} + d_{prop} + d_{proc}] \quad (2)$$

In (2) d_{trans} is the transmission delay, d_{prop} is the propagation delay, d_{proc} is the processing delay in the queue and k is the number of peer association in each peer. So, the context aware utility of individual peer association is,

$$U_\mu(k) = \frac{L(\mu,\rho,n)}{d_{ratio}} \quad (3)$$

$$d_{ratio} = \frac{d_{end}}{d_{max}} \quad (4)$$

In (3), the context aware utility function captures different application specific QoS requirements like data rate and delay. In (4), the delay ratio d_{ratio} is between the current end-to-end delay $d_{end}(k)$ and the maximum end-to-end delay $d_{max}(k)$ is that the application can tolerate for achieving the QoS guarantee. So the resource allocation problem becomes the following optimization problem,

$$\max \sum_{n=1}^{\mu_n} U_{\mu_n}(k) \quad (5)$$
$$s.t.\ L_{min} \le L \le L_{max}$$
$$d_{ratio} < 1$$

The optimization problem in (5) is the utility maximization problem where by allocating the optimal bandwidth $L^*(\mu, \rho, n)$, the utilities of different the peer association μ_n increases.

3. Context-aware peer association game

Based on the system model in section 2, the Irving's matching algorithm [6] is applied to create the one-to-one peer association μ. The preference list $P = \{p_1, p_2, .., p_n\}$ of each peer in M is sorted in an increasing order based on the context-aware utility function $U_\mu(k)$. In order to create the one-to-many peering, the refined Irving's matching algorithm is extended as in [7].

4. Simulation

Table 1 Simulation Parameters

Number of Devices, M	20
Max data rate	~ 50 Kbps
Min data rate	~ 30 Kbps
Delay ratio	< 1 ms
WiFi-Direct range	100 m
Packet size	2048 bit
Peer Time	100 s

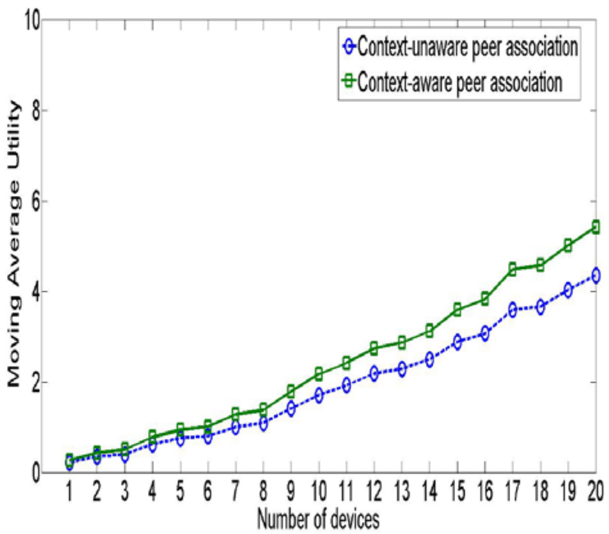

Figure 2 Comparison results showing the Context -aware approach and Context un-aware approach

Fig. 2 illustrates the efficiency of the optimal network resource allocation. The moving average utility of the proposed context-aware peer association outperforms the context-unaware peer association. The proposed optimal network resource allocation scheme shows efficiency which eventually increases the positive externalities of the P2P IoT network through the context-aware peer association utility.

5. Conclusion

In this paper, we have proposed an optimal resource allocation scheme for P2P IoT network. The simulation result shows the efficiency of the proposed resource allocation scheme in case of context-aware P2P IoT peer association with externalities.

Acknowledgement

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