



Custom Network Protocol Stack for Communication Between Nodes in a Cloudlet System

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ABSTRACT

With the advent of internet of things (IoT), new network paradigms have emerged. One such technology is cloudlets. Cloudlets are being increasingly used in various IoT-based applications such as smart homes, smart cities, healthcare, and industrial automations. Cloudlets have an advantage of proximity to the end-device while offering services similar to the cloud. Existing cloudlets use IEEE 802.11 for communication between nodes. In this paper, the authors present a protocol customized for usage in cloudlets, which also considers various limitations of the node that constitute the cloudlet. The nodes on the cloudlet are generally constrained in terms of power and memory when compared to nodes on a cloud. The custom protocol also incorporates fault-tolerance, time synchronization, and factors such as task affinities for communication. The protocol proposed in this paper gave an excellent packet delivery ratio, the lowest being 91% even with increased bandwidth usage when compared to IEEE 802.11.

KEYWORDS

Cloudlets, Cross-Layer Network Stack, Dynamic TDMA, Time Synchronization, Internet of Things (IoT), Industrial IoT

With advances in internet of things (IoT) research, new computing paradigms have emerged (Pham et al., 2022). Billions of edge devices are part of multiple application domains in IoT. One of the primary areas of applications of IoT (Malik et al., 2021) is in industrial systems. Industrial IoT currently uses either edge or server-based computing due to the necessity of securing data. While large industrial complexes may employ a private cloud (Prajapati et al., 2018), medium or small-scale industries prefer edge computing (Khan et al., 2019). Edge computing requires powerful coordinators connected to

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the end device to process the data (Cao et al., 2020). Industrial networks are inherently hierarchical (Galloway & Hancke, 2012); one possible solution is using cloudlet systems. The cloudlet layer is an extra layer introduced between the edge of the IoT system and the cloud. The cloudlet layer could handle short-term data processing and control decisions, while long-term data storage can be done on the cloud.

We have built a cloudlet system using multiple Qualcomm DragonBoard 410c development boards (Kakade, 2023). Our earlier work (Kakade et al., 2023) details the distributed task-sharing algorithm used on the cloudlet framework. For tasks and data to be distributed efficiently among the nodes in the cloudlet, an ideal network protocol stack is required for communicating between the nodes in the cloudlet. Currently, most cloudlet systems use IEEE 802.11 for communication between nodes in the cloudlet.

The custom algorithm described in this paper is a novel algorithm which considers multiple parameters such as:

- processing load on the node
- storage space availability of the node
- number of active network connections
- type of node used in building a communication protocol between various nodes in the cloudlet

The distributed task-sharing algorithm requires regular communication between various nodes in the cloudlet to obtain information regarding the state of the node's processing power and available storage, as task migration decisions are made based on these parameters. The exchange of information is done at regular intervals so that the decisions are not based on stale information. Whether tasks are migrated or not, the nodes will communicate consistently between them based on their current CPU and storage status. This requires a standardised network protocol to achieve constant communication between the nodes.

The network protocol stack is a set of protocols that are used to enable communication between nodes in a cloudlet. These protocols define the rules and standards for transmitting data over the network, ensuring that information is sent and received correctly (Xiang & Shaobin, 2020). By using a network protocol stack, nodes in a cloudlet can communicate with each other efficiently, enabling seamless data transmission and ensuring the integrity of the information being exchanged. Additionally, the network protocol stack allows for effective resource management within the cloudlet, enabling optimal utilisation of available network resources and ensuring smooth operation of various services within the cloudlet.

The significant contribution of this paper is novel custom-built network protocols explicitly designed for communication between nodes in a cloudlet environment. These custom-built protocols are optimised for cloudlet networks' unique characteristics and requirements, ensuring efficient data transmission and low latency. The development of this custom protocol is a significant contribution to the field, as it addresses the specific challenges and optimisations needed for effective communication within a cloudlet. Furthermore, the paper provides an in-depth analysis of the performance and effectiveness of this custom protocol compared to traditional network protocol stacks, demonstrating the superiority in terms of speed, reliability, and resource utilisation. Overall, this paper highlights the importance of a network protocol stack in enabling effective communication between nodes in a cloudlet and demonstrates the value of a custom-built protocol.

To the best of our knowledge, this paper is the first to propose and implement a custom network protocol stack specifically designed for communication within a cloudlet. The results of our experiments show significant improvements in data transmission efficiency and network resource utilisation compared to traditional network protocol stacks.

The rest of the paper is organised as follows: the next section gives a brief introduction to cloudlets and the proposed cloudlet architecture, followed by a detailed description of the operation of the

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