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SDN BASED DEVICE TO DEVICE COMMUNICATION ARCHITECTURE FOR 5G MOBILE NETWORKS

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Abstract

Effective 5G mobile network requires many emerging technologies to cope with increasing number of mobile devices and huge traffic volume. The Device to device (D2D) communication and Software Defined Networks (SDN) technologies are introduced to handle network architecture challenges. D2D communication may improve network throughput, energy efficiency, and spectrum utilization by enabling direct communication between proximity devices. On the other hand, SDN is promising network architecture that separates the control plane from data plane. Instead of adopting separate solutions, this paper proposes system architectural design by merging D2D and SDN technologies to improve mobile network performance. The design integrates the SDN controller of the SDN architecture and proximity server related to the D2D communication in one unit at the core network, named centralized controller. The centralized controller may have a global view about the network topology and its status; and therefore it can provide convenient and efficient approach to administrate SDN network and manage and operate direct D2D communication between two mobile devices. The proposed system considers efficient energy consumption during peer discovery and pairing procedures. Extensive simulation validates the effectiveness of the proposed system and shows that the proposed system achieves enhanced performance in terms of higher data throughput and low network latency.

Keywords: 5G, D2D, Device to device, SDN, Software defined networks.

1. Introduction

The rapid growth in the mobile devices number and the tremendous increase of multimedia applications represent the primary challenge for 5G networks. Extra mobile traffic is demanding due to the popularity of social media services, video streaming, and Internet games. However, the current mobile network architecture can't cope with this traffic pressure, and hence, new emerging technologies are proposed to overcome this issue

The new generation of 5G mobile network may further push the limit of the previous generations to provide higher data rate, low latency, and wider capacity. The implementation of 5G mobile networks require re-engineering in the design of existing networks and introducing new network technologies. The 5G research show an interest in various trends, such as very small mobile cells, Massive Multiple Input Multiple Output (MIMO) technique, millimetre wave (mm Wave), Software Defined Networks (SDN), Device to Device (D2D) communications and many others [1, 2].

Recently, there is an increasing interest in the development of mobile network architecture. Different from the previous standards (2G to 4G) that implemented based on network centric approach, the 5G mobile networks moves toward device centric approach [3]. Therefore, mobile operators try to displace the traffic form the core network by developing several technologies. The D2D communication technology and SDN network architecture are considered the most remarkable techniques that introduced to overcome network architecture issues. These techniques may potentially solve the capacity bottleneck problem in mobile networks and provide low cost and energy efficient communications.

At the present time, there is an intensive attention in D2D communication technology due to its ability to deal with throughput hungry services and battery budget limitation of mobile devices. In this technology, two mobile devices can communicate directly with each other without relying on any mobile infrastructure entities [4]. Thus, there is a shorter link during proximity-based communication between mobile devices without the cost of additional infrastructure. This paradigm can provide several benefits. The proximity of mobile devices enables higher bit rates, lower delays, and improved energy efficiency due to lower power transmission of proximity devices. In addition to that, enhanced spectral efficiency can be achieved when offloading data from treasured spectrum to out of band technologies, such as Wi-Fi and Bluetooth.

Another key point, flexible and dynamic programmable network architecture can be achieved by using SDN technology. The SDN support a potential change in the way of the network operates by re-defining the network architecture. The complexity of many network operations can be addressed using software-based networks [5]. This new paradigm decouples the control plane from data plane. All the control functions may be concentrated on a centralized controller and leave traditional switches for forwarding data only at access network [6]. This offers several benefits such as virtualized networking, on-demand resource allocations and secure cloud services.

Most proposals adopted one of the two mentioned technologies for 5G mobile networks; meanwhile the available suggestions for merging these techniques ignores the power consumption and may cause high signalling and handover latency. In addition there is no detailed simulation for integration. Accordingly, benefits from these two promising technologies, this paper proposes a flexible and improved network framework by integrating SDN architecture and D2D communication technology to provide a systematic solution for 5G mobile networks. The proposed design considers the mobile device energy consumption and the network latency and throughput.

The reminder of this paper is organized as follows. Section 2 discusses related studies in D2D and SDN technologies. Section 3 presents the details of D2D communication technology and SDN architecture for 5G networks. The design of the proposed system architecture is described in Section 4. Section 5 explains the simulation details and results obtained and Section 6 concludes the paper.

2. Related Work

As there are several key technologies investigated for future 5G mobile networks, the network architecture received critical attention. A considerable amount of literature has been published on D2D and SDN technologies.

The details of 5G mobile technology are given in [7] where the authors presented a comprehensive overview of the current status and the future of 5G mobile network technology options. Tayyaba and Shah [8] discussed the challenges and issues for the integration of 5G networks with SDN architecture. In the same way, Shen [9] described the emerging market requirements for D2D communication to improve communication capabilities, especially for 5G mobile network. Moreover, Shah et al. [10] presented a contemporary survey of the D2D communication technology. However, there are few works that merges these technologies in one system architecture. This section presents a critical review on the available works that integrates D2D and SDN for 5G networks.

Usman et al. [11] proposed a hierarchal D2D communication system using mobile cloud head and benefiting from SDN controller. The concept of SDN centralized controller was used to work in case of infrastructure damage and hotspot traffic situation. In this work, the user equipment runs a mobile cloud application and broadcasts requests to nearby devices to collect information. Mobile cloud then passes this information to the SDN controller in which it can control the connection between mobile devices. However, this approach consumes Mobile Node (MN) battery power due to continuous broadcasting requests to nearby devices. In addition to that, the authors focused on importance of public safety applications for D2D communications in commercial cellular networks and they didn't present any evaluation for their work.

Cai et al. [12] studied the integration of D2D communication with SDN framework and network function virtualization. This work addressed the challenge of resource sharing problem in mobile wireless networks. The authors used Network State Information (NSI) including channel state information and queuing state information to deal with this issue. Even though the authors evaluated their model analytically, they only interested on the in-band D2D communication that uses licensed spectrum of the mobile network. Important to realize that the in-band D2D communication may increase the possibility of interference issue between direct D2D and cellular network since they use same spectrum for their communications.

Zhou et al. [13] proposed a hierarchal SDN architecture that used two tier centralized controller for D2D communication. For the control plane, the authors suggested multiple Local Controllers (LCs) and a logically centralized global Controller (GC). The GC performs events of multiple cells with multiple LCs and takes global view of the network, while LCs handles simple decision for local events within a cell. In the data plane, two types of mobile nodes are proposed; enhanced node (EN) and an ordinary node (ON). The ON node only deals with LC data transmission, meanwhile the EN node has a combined function of ON and wireless switch to help other nodes to forward their packets. Even though the authors claimed for transporting of data packets in flexible and efficient way, the suggested model is too complex for implementation and considers new network devices.

Jayadi and Lai [14] proposed wireless network architecture for efficient D2D multihop D2D communication using SDN technique. In this approach, the mobile node has the capability to relay data to nearby devices hop by hop until the data reaches to its final destination. Thus, the coverage of D2D communication may be increased form near mobile devices to those are far away. However, the proposed approach deals with only in-band D2D communication links that are on the same spectrum of mobile network. This may increase interference issue in mobile network. Moreover, the authors didn't consider the power consumption of the mobile devices. Another hierarchical architecture of D2D communication using SDN is discussed by Muthanna et al. [15]. The centralized SDN controller may interact with cloud head to reduce the number of requested LTE communication channels. Even though the authors claimed for reducing power consumption, but there is notable power consumption due to mobile device frequently broadcasting request to nearby devices. In addition, the presented simulation is too limited and uses mesh network instead of conventional mobile network.

Cheng et al. [16] studied D2D Wi-Fi offloading scheme by utilization of SDN technology. The authors suggested that each mobile device periodically sends its current context to SDN controller. When the SDN controller detects those two mobile devices communicating using mobile link on the same Wi-Fi access point area, it informs the mobile devices to switch to D2D communication using Wi-Fi link. This approach shows two issues. First, periodically transmitting of MN context to SDN controller may lead to mobile node power consumption and also cause traffic load on the network. Second, the SDN controller gives signals to D2D communication only when the mobile nodes are in the same Wi-Fi access point area. However, there is possibility to perform D2D communication between two mobile devices on adjacent access point's areas.

By summarizing the review of the previous studies, the following challenges are found:

- The main drawback of previous studies is the D2D communication link may be established based on the link specification between access point and mobile nodes which may be inappropriate for direct D2D communication between two mobile nodes.
- There is no detailed method for mode selection to decide whether the devices should communication directly or through network infrastructure, i.e., differentiate between D2D direct connection and return to infrastructure mode without link disconnection.

- Lack power efficiency due to continuous mobile node scanning for nearby devices which consumes battery power.
- There is traffic issue on the network since the mobile node sends its context to SDN controller periodically.

The main aim of this paper is to design and evaluate SDN based D2D communication architecture using out of band technologies, such as Wi-Fi for future 5G mobile networks. The design considers the above-mentioned challenges.

3. Enabling SDN and D2D Communication for 5G Mobile Networks

Compared to 4G, 5G mobile network may achieve around 100 times data traffic, 1000 times system capacity, 10 times spectral efficiency, 100 times more connected devices, 5 times lower latency, and 10 times lower battery life for low power devices [17]. Currently, there are several trends for 5G mobile networks to cope with many challenges and requirements of future networks [18]. This study only focuses on D2D communication and SDN network technologies in order to improve mobile network architecture.

3.1. D2D communication for 5G networks

The D2D Communication is one of the component technologies for 5G mobile networks. It is expected to play an indispensable role in the approaching era of wireless communication [19]. In previous mobile generations, the mobile operators didn't focus on D2D communication system as a technique to improve mobile network performance. This is due to its limitation to local communication services. Recently, the attitude of mobile operators has been changed due to several trends in the wireless market. The increasing popularity of context-aware services and mobile applications based on proximity devices led to introduce and develop D2D communication technique. These new developed mobile applications require location discovery and communication with neighbouring devices. As a result, the D2D communication is becoming a vital part for 5G networks. The D2D communication provides flexible infrastructure capabilities for operators to offload mobile traffic from the core network at the access network. This may reduce the energy and communication cost especially for proximity-based services such as social networking.

The D2D communication allows data flow between two mobile devices without any mobile base station or core network participation. A direct communication link can be established between proximity devices using D2D technique. A proximity server in D2D communication architecture is introduced to manage the operation of D2D communication, as shown in Fig. 1. The proximity server identifies the proximity between mobile devices and then triggers direct D2D communication link when needed. Power saving of mobile node is one of the main benefits for using D2D communication due to the shorter link between mobile devices compared to the link between mobile devices and base station. In addition, this technique promises several improvements compared to infrastructure-based system, especially for raising system throughput of the whole network and reducing network traffic latency [3].

There are two types of D2D communications, in-band D2D communication and out-band D2D communication. For in-band D2D communication, the communication occurs on the mobile network licensed spectrum. Thus, the licensed spectrum is used for both mobile links and direct D2D communication links. Even though this type of D2D communication may provide a considerable control over licensed spectrum, but it leads to high interference issue between D2D and cellular links. Different form in-band D2D communication, the out-band D2D communication exploits unlicensed spectrum such as Wi-Fi, ZigBee, or Bluetooth. Therefore, the mobile device in out-band D2D communication benefits from the additional Wi-Fi interface in most mobile devices. The main motivation for using out-band D2D communication is removing the interference issue between D2D communication links and cellular communication links [3, 19].

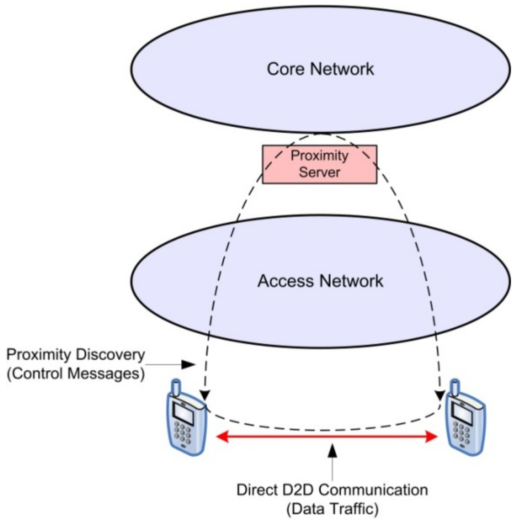

Fig. 1. D2D Communication structure.

3.2. SDN architecture for 5G networks

SDN is an emerging network paradigm to design, implement, and manage networks in which the control decision is decoupled from forwarding hardware [20]. The SDN architecture was developed to simplify network management and facilitate innovation and evolution. The SDN architecture enables network programmability and supporting heterogeneous network in which the organizations can easily deploy their applications for a better user experience. The SDN enables centralized network intelligence with SDN controller at the control plane, while other network devices are considered as simple forwarding devices at the data plane. Accordingly, the network administration and management are simplified since the information related to logical network topology and the routing of traffic are processed at the control plane. On the other hand, the data plane coordinates the network traffic based on the established configuration in the control plane. This network segmentation may provide several advantages in terms of network flexibility and controllability since the SDN controller have a global view of the network.

There are two well-known SDN architectures, namely (ForCeS) Forwarding and Control Element Separation, and Open Flow [21, 22]. Even though these architectures are technically different in terms of design, forwarding model and protocol interface, but they are proposed based on the same SDN separation principle between control and data planes. However, the Open Flow has been able to gather more attention as result of support from multiple sectors of industry, research and academia. In the Open Flow architecture, the forwarding device (or simply called Open Flow switch) at the data plane contains flow tables. The flow tables may include the flow entries that determine the forwarding and processing scheme at Open Flow switch, as can be seen in Fig. 2. The SDN controller can update, add, or delete flow entries at Open Flow switch using Open Flow protocol. The Open Flow protocol defines a set of instructions and messages between these entities that exchanged through a secure communication link.

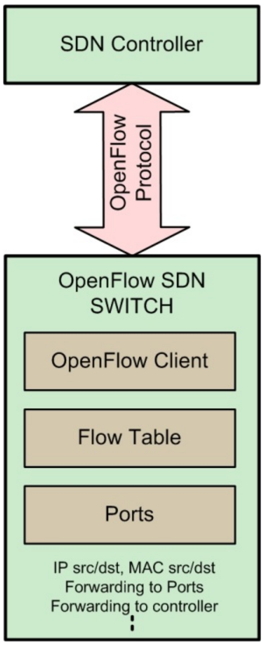

Fig. 2. SDN Network structure.

4. Proposed System Design

The basic idea of SDN based D2D communication is that the proximity services will benefit from information available in SDN controller to manage D2D communication. In our proposed architecture, the proximity server in D2D communication system and the SDN controller in SDN architecture are integrated and placed in one unit at the core network. In this way, there is one centralized controller that collects information about all mobile devices and access points (or base stations) in the network. Thus, the centralized controller may have global view about the network topology and its status. As a result, the centralized controller can provide convenient and efficient approach to administrate SDN network and enable direct D2D communication.

In brief, the operation of proximity services can be divided into two phases, peer discovery phase and direct D2D communication phase. In peer discovery phase, the mobile device discovers other devices that are in proximity based on device information or network assisted information. The second phase of direct D2D communication is enabled when two mobile devices are available in proximity to each other. However, peer discovery is considered the main challenge in D2D communication since the two mobile devices need to know each other before start communication. Typically, peer discovery without network assistance and support is time and energy consuming. This is due to continuous mobile scanning using beacon signals with security procedures involvement at higher layers. In construct, network assisted peer discovery is faster, efficient energy consumption and more user friendly.

Generally speaking, many companies, operators, organizations, and other stakeholders are recognizing that D2D communication will be cornerstone of future 5G mobile network. This can be seen clearly from the Wi-Fi direct specifications and proposals development for LTE-A D2D standardization. Thus, in this architecture design, a network assisted D2D communication system is proposed using out-band technology of Wi-Fi interface to overcome interference issue at mobile licensed spectrum. Accordingly, the mobile devices may use the cellular network to transmit information during normal link and switch to the Wi-Fi interfaces whenever direct D2D communication is possible.

In practice, the operation and management algorithms of proximity server related to D2D communications are implemented on the top of SDN controller, as they are both working as a centralized controller. The SDN controller records the current context (such as current location, its Received Signal Strength Indicator RSSI, application type, flow type, and so on) for each mobile device on the network. Consequently, the centralized controller monitors mobile devices conditions in addition to the other measurements from the network. In our design, the mobile devices update its information only when there is a change in its condition, such as moving from one cell to another. Hence, the information of the mobile device is updated at the centralized controller using event-driven algorithm. Event-driven algorithm will overcome the drawback of periodically sending information message to centralized controller to update mobile device condition. Thus, two benefits can be obtained: first, reducing power consumption of mobile device and second, decreasing traffic processing on the network.

The centralized controller may define the route for each mobile device in the network since it gathers all the necessary information of mobile devices and the status of the network elements. Practically, for D2D communication, the procedures of peer discovery phase and direct D2D communication phase are managed by the centralized controller. Thus, the centralized controller unit decides whether to perform infrastructure-based communication mode through mobile network spectrum or utilizing direct D2D communication mode through Wi-Fi spectrum. In addition, the centralized controller may determine which access point or base station is suitable for routing the traffic information. This is necessary to balance the traffic load at the access network and overcome network bottleneck.

The direct D2D communication can be occurred between two mobile devices on proximity. This may occur when the mobile devices are on the same cell, or on neighbouring cells. Accordingly, when the centralized controller detects such condition based on the available collected information, it notifies the two mobile devices to start sending Wi-Fi Beacons signals in order to find each other. This happens in the peer discovery phase. When the two mobile devices in physical proximity detects that the RSSI received in each device is suitable for direct communication, they inform the centralized controller. The centralized controller in turn triggers the two mobile devices to change from mobile infrastructure-based communication into direct D2D communication using Wi-Fi interfaces. Thus, direct D2D communication phase is working to perform data transmission between mobile devices.

The D2D communication structure will be continue until completing transmission or until the RSSI of Wi-Fi link between the two mobile devices decreased to pre-determined value. This condition may happen when the mobile devices moving out of mutual signal coverage. According to this case, the mobile devices inform the centralized controller in order to prepare the available mobile cells to return mobile nodes. As the RSSI continue deceasing, the mobile devices report centralized controller to return to the infrastructure communication mode before losing direct D2D communication link. Under those circumstances, the centralized controller will continuously monitor the communication situation of the two proximity devices based on their received context in order to support reliable communication condition. This is necessary for the centralized controller to judge if the mobile devices will continue using D2D communication or it should be reverting to infrastructure mobile mode when RSSI link quality degrades between them

There are several advantages of the proposed design: first, reducing power consumption as the mobile devices send beacons searching for other proximity devices based on the trigger from centralized controller only. Second, it supports efficient communication because the direct D2D communication link is established based on RSSI between the two proximity devices rather than based on RSSI between mobile devices and base station. Third, it provides reliable communication since the communication between mobile devices will continue between mobile devices without any interrupt, i.e., there is no connection lost when returning from D2D communication to mobile infrastructure mode.

5. Simulation Implementation and Results

The proposed model has been implemented and evaluated using NS2 network simulator to compare the D2D communication mode performance against conventional infrastructure mode [23, 24]. The detail of the network topology is shown in Fig. 3. The network includes nine mobile cellular cells at the access network connected to the Router. The Router is connected to the centralized controller at the network core. The default link delay is considered 1 millisecond for all connections. The centralized controller was developed by integrating SDN controller and proximity server functionalities. The SDN controller registers mobile nodes traffic flows and their locations. Also, the SDN controller may collect other network measurements related to each mobile node. The proximity server is implemented on the top of the SDN controller, and it may be triggered by SDN controller based on the available information regarding mobile nodes locations. The proximity server enables peer discovery and direct D2D communication for D2D communication case.

In the proposed system implementation, each mobile node is supported with two communication interfaces, which are the cellular interface and Wi-Fi interface. The mobile node may use cellular network interface to update its current information (location, RSSI) at the centralized controller. Based on received information from all mobile nodes, the centralized controller can identify if the two mobile nodes are in the same or neighbouring cells in order to run direct D2D communication procedure through Wi-Fi link. Accordingly, the proposed centralized controller is aware of the overall connectivity information of the network. That means the centralized controller manages traffic flows for SDN based network and also controls the switching between infrastructure communication mode (through mobile cellular network) and D2D communication mode (through Wi-Fi link).

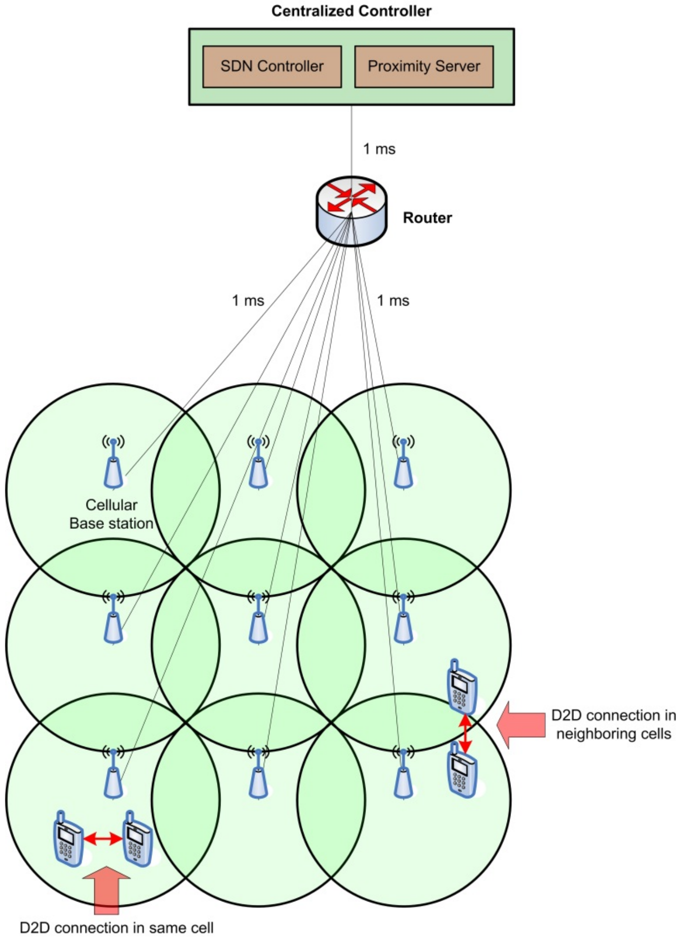

Fig. 3. Simulation network topology.

Figure 4 illustrates the end-to-end delay of the packets transmitted between two mobile nodes at the network when they are moving in the same cell. The figure shows the end-to-end delay of the packets during infrastructure cellular mode and when switching to direct D2D communication mode. It can be noted that the infrastructure mode shows an average of about 7 ms end to end delay, meanwhile the D2D communication gives an average of 1.5 ms. Thus, the infrastructure mode gives higher end to end delay compared to D2D communication mode. This outcome is attributed to the processing delay at the cellular base station in addition to the high propagation delay between mobile nodes and base station during the infrastructure mode. In construct, during D2D communication the mobile nodes exchanges information directly and benefits from shorter communication link between them.

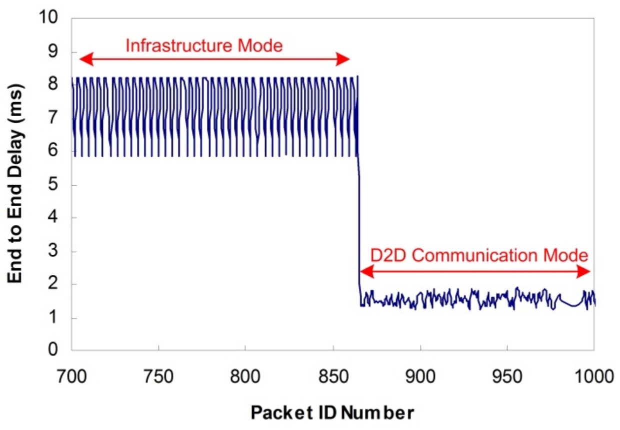

Fig. 4. End to end delay for D2D and infrastructure modes in the same cell.

Figure 5 depicts the variation of the end-to-end delay during mobile nodes movement on neighboring cells. It is clearly seen that the D2D communication mode presents lower end to end delay compared to infrastructure mode. However, the infrastructure mode gives around 9 ms end to end delay, around 2 ms higher than infrastructure mode in Fig. 4 when the two mobile nodes are moving in the same cell. This is due to the links delay between each base station and the Router that connected them.

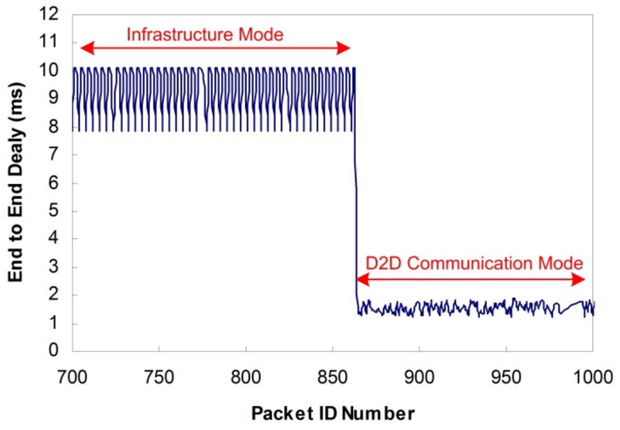

Fig. 5. End to end delay for D2D and infrastructure modes in the neighboring cells.

Figure 6 presents throughput performance analysis during infrastructure communication mode and D2D communication mode. Clearly noted that the D2D communication mode shows higher throughput with 60 Mbps compared to infrastructure mode that generates 20 Mbps. The reason is related to the higher bandwidth supported by Wi-Fi link during D2D communication mode compared to bandwidth available by cellular network in infrastructure communication mode.

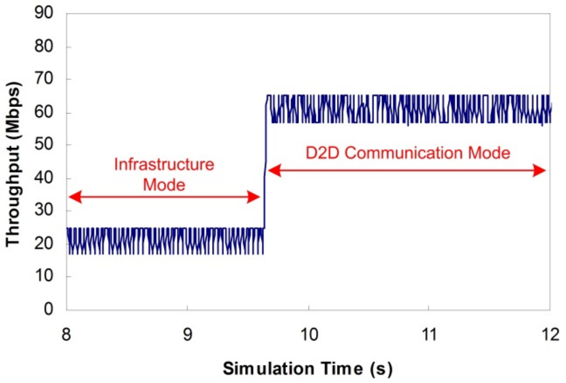

Fig. 6. Throughput for D2D and infrastructure modes.

The effect of the traffic load on the two communication modes is presented in Fig. 7. Different traffic types can be generated by varying the packet interval between successive packets. Generally, large packet interval indicates low data rate such as voice, whereas small packet interval signifies higher data rate such as video. Accordingly, the small packet interval may generate high end to end delay due to heavily data load traffic. It can be seen that infrastructure mode generates higher end to end delay at small packet interval compared with D2D communication mode and decreased gradually as the packet interval increased. However, D2D communication mode provides lower end to end delay performance and thus improves the quality of service for various mobile applications.

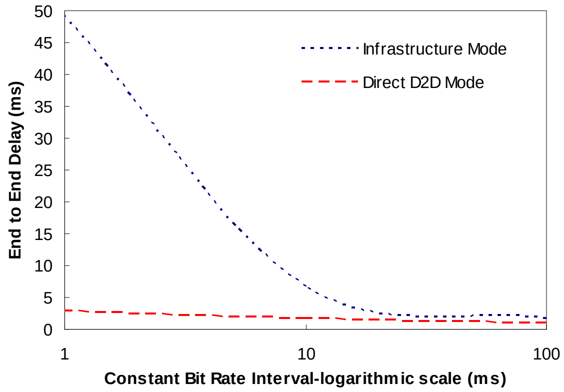

Fig. 7. Impact of bit rate on the end to end delay for D2D and infrastructure modes.

Figure 8 illustrates the effect of traffic load at the network, specifically at the Router. A simulation scenario with 12 mobile nodes at the network with 6 communication links between them, i.e., one communication link between each two mobile nodes. At the beginning, all mobile nodes are communicating through infrastructure cellular network. Thus, all the traffics are moving through the Router. Gradually, one direct D2D communication link is generated at a time between two mobile nodes in order to study the effect of the end-to-end delay at the Router. It can be noted that the end-to-end delay at the Router reduced gradually as the number of direct D2D communication link generated increased. Hence, D2D communication reduces the traffic load at the cellular network and then can enhance the operation of the network. This result is attributed to the reduction in the end-to-end delay and network devices processing delay.

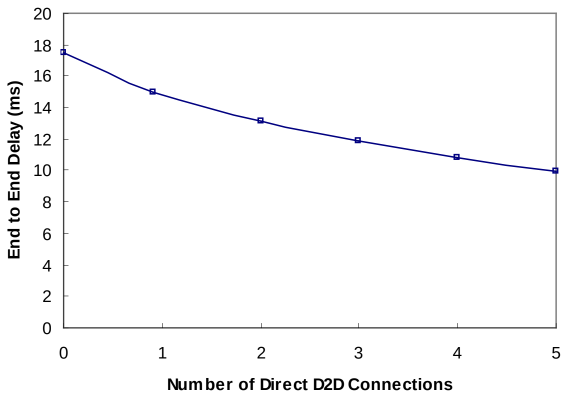

Fig. 8. Impact of the number of D2D links on the end to end Delay.

6. Conclusion

The D2D communication and SDN technology are two promising paradigms to cope with network architecture challenges in 5G mobile networks. This paper integrates the D2D and SDN technologies in one system architecture to improve network performance. The proximity services for D2D communication are established under SDN guidance.

The proposed system uses out-band Wi-Fi technology to overcome interference issue at mobile licensed spectrum. Instead of frequent scanning for nearby devices, the information at the centralized controller is updated using event-driven algorithm to reduce the power consumption and improves the battery life of mobile device. The switching between infrastructure mode and D2D communication mode will be performed before losing signal to provide reliable communication between mobile devices.

The system implementation and evaluation show that the D2D communication improves the performance of the network especially in terms of reducing end to end delay and increasing data throughput.

The future work may focus on the flexibility of the centralized controller framework to support additional communication functionalities such as multi-hop wireless communication.

References

1. Gupta, A.; and Jha, R.K. (2015). A survey of 5G network: Architecture and emerging technologies. *IEEE Access*, 3, 1206-1232.
2. Kabalci, Y. (2019). *5G mobile communication systems: Fundamentals, challenges, and key technologies: Smart Grids and Their Communication Systems*. Singapore: Springer.

3. Mumtaz, S.; Huq, K.M.S.; and Rodriguez, J. (2014). Direct mobile-to-mobile communication: Paradigm for 5G. *IEEE Wireless Communications*, 21(5), 14-23.
4. Seyedebrahimi, M.; Raschellà, A.; Bouhafs, F.; Mackay, M.; Shi, Q.; and Eiza, M.H. (2016). A centralised Wi-Fi management framework for D2D communications in dense Wi-Fi networks. *2016 IEEE Conference on Standards for Communications and Networking, CSCN 2016*, 1-6.
5. Rost, P.; Banchs, A.; Berberana, I.; Breitbach, M.; Doll, M.; Droste, H.; Mannweiler, C.; Puente, M.A.; Samdanis, K.; and Sayadi, B. (2016). Mobile network architecture evolution toward 5G. *IEEE Communications Magazine*, 54(5), 84-9.
6. Nunes, B.A.A.; Mendonca, M.; Nguyen, X.N.; Obraczka, K.; and Turletti, T. (2014). A Survey of software-defined networking : Past, present, and future of programmable networks. *IEEE Communications Surveys & Tutorials*, 16(3), 1617-1634.
7. Osseiran, A.; Monserrat, J.F.; and Marsch, P. (2016). *5G mobile and wireless communications technology*. Cambridge University Press.
8. Tayyaba, S.K.; and Shah, M.A. (2017). 5G cellular network integration with SDN: Challenges, issues and beyond. *In IEEE 2017 International Conference on Communication, Computing and Digital Systems, (C-CODE)*, 48-53.
9. Shen, X. (2015). Device-to-device communication in 5G cellular networks. *IEEE Network*, 29(2), 2-3.
10. Shah, S.T.; Hasan, S.F.; Seet, B.C.; Chong, P.H.J.; and Chung, M.Y. (2018). Device-to-device communications: A contemporary survey. *Wireless Personal Communications*, 98(1), 1247-1284.
11. Usman, M.; Gebremariam, A.A.; Raza, U.; and Granelli, F. (2015). A software-defined device-to-device communication architecture for public safety applications in 5g networks. *IEEE Access*, 3, 1649-1654.
12. Cai, Y.; Yu, F.R.; Liang, C.; Sun, B.; and Yan, Q. (2015). Software-defined device-to-device (D2D) communications in virtual wireless networks with imperfect network state information (NSI). *IEEE Transactions on Vehicular Technology*, 65(9), 7349-7360.
13. Zhou, M.; Zhang, H.; Zhang, S.; Song, L.; Li, Y.; and Han, Z. (2016). Design and implementation of device-to-device software-defined networks. *2016 IEEE International Conference on Communications (ICC)*, 1-6.
14. Jayadi, R.; and Lai, Y.C. (2017). Low-overhead multihop device-to-device communications in software defined wireless networks. *Proceedings of International Conference on Soft Computing, Intelligent System and Information Technology, ICSIIT 2017*, 144-149.
15. Muthanna, A.; Ateya, A.A.; Al Balushi, M.; and Kirichek, R. (2018). D2D enabled communication system structure based on software defined networking for 5G network. *2018 International Symposium on Consumer Technologies, ISCT 2018*, 41-44.
16. Cheng, R.S.; Huang, C.M.; and Pan, S.Y. (2018). WiFi offloading using the device-to-device (D2D) communication paradigm based on the Software Defined Network (SDN) architecture. *Journal of Network and Computer Applications*, 112, 18-28.

17. Iwamura, M. (2015). NGMN view on 5G architecture. *In 2015 IEEE 81st Vehicular Technology Conference (VTC Spring)*, 1-5.
18. Kumar, V.; Yadav, S.; Sandeep, D.N.; Dhok, S.B.; Barik, R.K.; and Dubey, H. (2019). 5G Cellular: concept, research work and enabling technologies. *Lecture Notes in Networks and Systems*, 39, 327-338.
19. Gandotra, P.; and Jha, R.K. (2016). Device-to-device communication in cellular networks: A Survey. *Journal of Network and Computer Applications*, 71, 99-117.
20. Benzekki, K.; El Fergougui, A.; and Elalaoui, A.E. (2016). Software-defined networking (SDN): a survey. *Security and Communication Networks*, 9(18), 5803-5833.
21. Jagadeesan, N.A.; and Krishnamachari, B. (2014). Software-defined networking paradigms in wireless networks: A survey. *ACM Computing Surveys*, 47(2), 1-11.
22. Kreutz, D.; Ramos, F.M.; Verissimo, P.; Rothenberg, C.E.; Azodolmolky, S.; and Uhlig, S. (2015). Software-defined networking: A comprehensive survey. *Proceedings of the IEEE*, 103(1), 14-76.
23. Issariyakul, T.; and Hossain, E. (2011). *Introduction to network simulator NS2* (2nd edition). Springer Science & Business Media, New York.
24. NS2 network simulator. Retrieved October 5, 2019, from http://www.isi.edu/nsnam/ns.