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SELF-OPTIMIZED AND TRAFFIC CONTROL WITH LINK PREDICTION HEURISTIC FOR HYPER-CONNECTED NETWORK

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ABSTRACT

Scalability, ultra-low-latency, high reliability and human & machine-centric communication features support high user density applications of high-quality enhanced multimedia services at high mobility. Multi-technology and multi-service framework of 5G connects the world at high speed and opens the path towards 6G. Knowledge of traffic content in advance can reduce the congestion in the network and enhance the performance and efficient utilization of the resources. In this paper, different resource utilization and link prediction hypothesis are presented to enhance the smart network performance in virtualized environment. TE-SDN controller with NFV and load-balancing heuristic is used for the creation of topologies which control the traffic efficiently and enhances the performance of the network by 50%. Open network distributed system provides the portal to handle the traffic at different locations using clustering technique used at the SDN controller also optimizes the network load

KEYWORDS

5G, SDN, NFV, traffic optimization.

1. INTRODUCTION

KPIs of the 5G technology and Smart intelligent networks enhance the performance of numerous Smart applications and business model which requires massive M2M communication, Low Latency Communication with high reliability (URLLC) and high speed mobile broadband (eMBB). 5G key building blocks are new radio and core network architectures, New Radio (NR) air interface, automation and virtualization technologies and new type of devices which helps in deciding 5G services target. Solid framework for enhancement of network performance and mass offering of amazing services opens the path for 6G. Intelligent, Deep, Holographic and ubiquitous connectivity is the objective of 6G. Presently we are moving forward for intelligent and fully automated 5G network, which supports everything as a service and utterly immersive experience, requires new heuristics and proper integration of bands. At the same time, green wireless network architecture with learning and decision capabilities requires advanced technologies of 5G and complete smart SDN system to support the business model (Barreto et al., 2016). Heterogeneous network demands efficient data and control decoupling, automatic resource adaptation, downlink and uplink decoupling, coordination of smart SDN controller and energy and spectrum efficiency. In this paper, link based traffic handling heuristic is presented. Uplink and downlink resource allocation scheme's main objective is minimization of user data rate and maximization of resource usage using link prediction heuristic in the smart network to enhance the fairness. The rest of the article is organized as follows. In Section II the state of art is described. Section III addresses link prediction heuristic, whereas Section IV considers the analytical model for stable and reliable link prediction. Section V presents simulation results and discussion. The paper finally draws conclusions in Section VI.2. STATE OF ART

2. STATE OF ART

Strong foundation for enhancements in high-performance NR air interface and flexible network architecture expand the applications of wireless communication. 5G LAN supports both fixed as well as wireless LAN which is more flexible and enhanced performance. Service ubiquity, service continuity and scalability are the objective of non-terrestrial networks (satellites). Online Healthcare section with minimization of cost requires all-time communication facilities of 5G (Sarigiannidis et al., 2017). Advanced driving, platooning and remote driving demands V2X facilities in the smart cities scenarios. Numerous scenarios to support medical facilities delivery in disaster area and remote sensitive areas 5G based UAVs services are used. Audio video production services demands high bandwidth availability of wireless communication without any interruption. Numerous logical networks are created by using same physical network resources to support different services demanded by different customers using network slicing. Service continuity, ubiquity and scalability are three use cases of 5G LAN. To handle all these applications, they are located near to the user equipment which allows the selection of gateway (gNB) to segregate the traffic passes through local gateway instead of core gateway, results in low latency (Luo et al., 2019). Off-shore wind farms, Smart agriculture, remote area manufacturing use-cases are feasible in satellite access which is not possible in terrestrial network due to economic parameter. Ultra-high definition contents can be easily broadcasted to many users simultaneously efficiently and economically in satellite networks from terrestrial network.

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Table 1: Difference between 5G and legacy network

Scenario	Network	
	Legacy Network	5G
D2D Communication	Computational Complexity & latency are Higher Two links require mitigation of potential interference	Low overhead on base station due to Local traffic is handled by adhoc and D2D communication Beamforming directive antennas mitigate the interference between two links
M2M Communication	Not efficiently handling M2M for massive devices, only can handle few hundred devices per base station. Real time scenarios for critical applications are not efficiently supported	SDN architecture and Hybrid RAN efficiently supports control and data planes. Time critical issues are resolved by low latency 5G requirements.
IoT	Connection of billions of sensors over internet requires fast communication.	High speed data rate to handle massive IoT devices with efficient resource utilization at the edge in programmable virtualization environment.

Big data, cloud, multimedia D2D, M2M and ICT domain are highly demanding more bandwidth for users to access internet and dynamically handling the business applications services. All these applications require an SDN controller, which handles large amount of interaction events with its associated programmable switching devices (Jing et al., 2020). Software optimization methods and heuristic analysis are used to enhance the performance of SDN controller and proper architecture framework helps in reducing the request frequency. Cloud computing and network function virtualization and explosion of connected devices raised the traffic exponentially and instability in usage patterns (Lai et al., 2015; Zhang et al., 2018). For this agile architecture is mandatory to support dynamic reconfiguration of network infrastructure as well as services to support. Traffic engineering and intelligent network system integration requires new technical standards and network slicing with virtual networks. Best subset of functions for QoS requires higher bandwidth and advanced technologies for end-to-end communications. Everything as a service is possible without virtualization and network slicing at lower cost.

Table2: Services supported by 5G technology

Service	Mechanism	Advantages
Channel/Frequency election	Required channel for communication is selected by SDN Controller	Resource Utilization proficiently
Route Selection	Balanced routing is obtained with SDN controller	Congestion Avoidance
Self-Healing	Detection, diagnose and recovery rules are defined by SDN controller	Spontaneous recovery against attack
Network forensics	Data Flow Monitoring and detection of device modification configuration	Attacker Identification
Detection of malicious behavior	Vehicle node or RSU using probe technique performs detection	SDN controller Load balance and easy implementation
Intrusion Detection	Traffic Behavior Analysis and SDN controller handle the intrusion detection	Security features are enhanced as compared to traditional network

3. ANALYTICAL MODEL FOR LINK PREDICTION HEURISTIC

Hypothesis of constraint-delay networks and suitable and adequate conditions to have probabilistic bound-delays in the network requires traffic shaping properly at the edge of the network. As long as a network is job-conserving, autonomous of the algorithms used in the switches for packet scheduling and queue management it results better network performance. A deterministic boundary-delay in the network, using the derived theorems can fulfil these characteristics (Sethi et al., 2019; Aqib et al., 2019). Without change in core network with support to both bursty and periodic traffic patterns with synchronization it supports various traffic classes in different bounded-delays. Between two mobile nodes, connection reliability is represented by the degree of association stability with respect to each other with regard to time and space. A significant factor for network performance is route stability, which is subject to connection failure due to node mobility (Abinader et al., 2014; Bradai et al., 2020). For communication purposes between source and destination, the issue of path stability and link availability while nodes travel along non-random patterns and prior knowledge of node movement is important to predict path discontinuity. At a specified time instance, an active path period is the time duration when one of the connections is inaccessible along the route when the communication route between the source and destination node is formed. The probability of accessibility of routes and length of paths before time is calculated under the model used for mobility (Sanguinetti et al., 2015). An acronym for nodes progression traveling as per the Random Direction or Random way point model is derived which, provided the initial state, is inverted to obtain the temporal evolution and PDF under no deposition. In the case of a large hop-count limit, using an exponential distributed function, the likelihood of path length distribution is correctly defined since the route is sufficiently large, regardless of which mobility model is assumed. The map structure and other detailed node parameters are used to obtain empirical exponential distribution parameters from the node density (Marwan et al., 2017; Sethi et al., 2019).

Figure 1: Resource utilization with load balancing at different servers

4. EFFICIENT & STABLE ROUTE ELECTION AND MAINTENANCE

With common radio range R in a bi-dimensional area, network of homogeneous nodes with same mobility pattern is formed for simulation purpose. Independent movement of all the nodes with respect to each other with a free space propagation model means from the transmitter distance is used to measure the received signal strength. At time t , position of two generic nodes S and D is $XS(t)$ and $XD(t)$ with a distance of $dS,D(t) = ||XS(t) - XD(t)||$. Two nodes are in the radio range R of each other, a communication link is established between (S, D) represented as $dS,D(t) < R$ which is bidirectional in behaviour. The probability of active link between nodes at time t is:

$$S_{link}(d_{S,D}(0), t) = P(d_{S,D}(t) < R | d_{S,D}(0)) \quad (1)$$

Link duration probability $LD_{link}(d_{S,D}(0), t)$ is the uninterruptedly active time t of a communication link between S and D with its initial distance $d_{S,D}(0)$, $0 < d_{S,D}(t) < R$

$$LD_{link}(d_{S,D}(0), t) = P(\inf\{\tau \text{ s.t. } d_{S,D}(\tau) > R\} > t | d_{S,D}(0)) \quad (2)$$

A path of N hops in a simulated network is observed by visiting $n+1$ node with sequence $1 \rightarrow 2 \rightarrow 3 \rightarrow \dots \rightarrow n \rightarrow n+1$. At a given instant of time, path probability is given as:

$$S_{\text{path}}(d0, t) = P(\text{des}_{i,i+1}(t) < R, V_{i \leq n} | \text{des}_0) \quad (3)$$

While the live route duration probability is the probability that a route has been uninterruptedly active time t

$$LD_{\text{path}}(\text{des}_0, t) = P(\inf\{\tau, s.t \text{ for some } i, i \in R\} > t | \text{des}_0) \quad (4)$$

During move phase, each node using Random Direction model to pause phase at alternate periods of movement, every time node elects its new direction and speed of movement. For complete duration direction and speed is kept constant during move phase; distribution of pause and move phases are represented as independent random variables. Either in the pause or in move phase of the node position temporal evolution can be described as partial differential equations.

4.1 Node Spatial Distribution

Over a general state space, Markov process is used to describe node motion dynamics with node state

- the phase $P(t) = P = \{\text{mov}, \text{pau}\}$,
- position $X(t)$ and present velocity $V(t)$

PDF of move phase of a node at time instance t over the state space is

$$v, t) = P(t) = \text{mov}, X(t) \leq x, V(t) < v \quad (5)$$

PDF of pau phase $p(x, t)$

$$P(x, t) = P(t) = \text{pau}, X(t) \leq x \quad (6)$$

4.2 Link Availability

Using the spatial pdf of nodes motion under RD model, an exact expression for probability of link availability at time instance t is represented in this section. Two nodes S and D , in move and pause phase under spatial distribution is represented with $MS(x, t) = \int mS(x, v, t) dv$ and $pS(x, t)$ for S and $MD(x, t) = \int mD(x, v, t) dv$ and $PD(x, t)$ respectively.

4.3 Link Duration

Link duration probability expression under random direction model is discussed in this section. In a state space, relative motion between source and destination S and D can be specified in terms of Markov process and by solving the corresponding equations given by Chapman Kolmogorov and link duration probability is estimated. Under the Brownian motion, expression for the link duration with rough approximation could be estimated by plugging the instantaneous variance of the node. Due to dominant term used under Brownian motion in the link duration, as the time goes infinite the probability of link duration decays exponentially. Multi Hop paths consider the path of n (bidirectional) links obtained traversing the $n+1$ nodes in sequence.4

$$S_{\text{path}}(\text{des}_0, t) = \prod_{i=1}^{n-1} S_{\text{link}}(\text{des}_{i,i+1}(0), t), \quad (7)$$

$$S_{\text{path}}(\text{des}_0, t) = P(\text{des}_{1,2}(t) < R, \text{des}_{2,3}(t) < R)$$

$$P(\text{des}_{1,2}(t) < R, \text{des}_{3,4}(t) < R | \text{des}_{2,3}(t) < R)$$

$$x P(\text{des}_{2,3}(t) < R) \quad (8)$$

$$S_{\text{path}}(\text{des}_0, t) = P(\text{des}_{1,2}(t) < R, \text{des}_{2,3}(t) < R)$$

$$P(\text{des}_{3,4}(t) < R | \text{des}_{2,3}(t) < R) P(\text{des}_{2,3}(t) < R) \quad (9)$$

$$S_{\text{path}}(\text{des}_0, t) = P(\text{des}_{1,2}(t) < R, \text{des}_{2,3}(t) < R, \text{des}_{3,4}(t) < R, \text{des}_{4,5}(t) < R)$$

$$P(\text{des}_{1,2}(t) < R, \text{des}_{2,3}(t) < R, \text{des}_{3,4}(t) < R) \quad (10)$$

$$P(\text{des}_{4,5}(t) < R | \text{des}_{3,4}(t) < R)$$

4.4 Optimal Path Selection

Path selection between nodes S and D using intermediate nodes as relay in wireless communication with maximum route stability in response to node mobility is observed under two scenarios. Few long hops and many short hops are two cases where preferable is short hops while considering if one connection fails, entire path fails with respect to nodes moving independently.

Expression for link availability under unidimensional Brownian motion with infinitesimal variance δ^2 is represented as:

$$S_{\text{link}}(\text{des}_{A,B}(0), t) = 1 - Q((R + \text{des}_{A,B}(0))/\sqrt{2 \delta^2 t}) - Q((R - \text{des}_{A,B}(0))/\sqrt{2 \delta^2 t}) \quad (11)$$

Where Q represents the normal distribution with zero mean and unit variance optimal number of hops 1D in Brownian motion

$$N_{1D} = \max(L/R(L/\sqrt{2 \delta^2 t})\sqrt{1 + R^2/4 \delta^2 t}) \quad (12)$$

$$N_{2D} = \max(L/R(L/\sqrt{2 \delta^2 t})\sqrt{1 + R^2/4 \delta^2 t} - L/2\sqrt{2 \delta^2 t})$$

5. SIMULATION

SDN switches are simple, easy to manufacture and cheaper with separate control plane with specification of more memory, higher processing speed and integration with other technologies. Minimizing traffic latency and optimising throughput is the objective of secure route selection. Through simulation, with previous prediction of node movement and probability analysis of expected route accessibility, all response time of source-destination routes is important to help plan a stable route.

Figure 2: Traffic Optimization with centralized unit when unnecessary flow drop occurs

6. PERFORMANCE EVALUATION

At all the terminals in a network, sum of delivered all data rates represent the throughput of the system. Along the selected path, average number of calculated steps is described as Path Length, which shows the efficiency of data transmission on the network. Load balancing is performed by the intelligent heuristic at the SDN controller or cluster node in the used topology.

Figure 3: Throughput of the different devices at different intervals

Figure 4: Round trip time of the different devices at different intervals

Existing algorithms considers fixed resource allocation and impact of flows on each other is not considered. Assume information flow x is transformed via path y with fixed resource allocation; in case of continues streaming flow even increase/decrease in bandwidth will cause in congestion or low link utilization. Optimization of link utilization is the objective of our heuristic.

7. CONCLUSION

Traffic engineering at different location of the heterogeneous network enhances the performance of the network. Intelligently handling of route formation and link prediction scheme in advance can enhance the performance of the network. In heterogeneous ad hoc network reliability and scalability are the prime concern while in LoRAprogrammability and delay are the prime objective. In massive IoT devices, due to small power consumed devices gateway plays an important role. The design principle for the 5G network SDN, Network slicing and NFV are represented for network performance automation. SDN Controllers have emerged as drivers of 5G network architecture and fuelled the development of a framework to provision dynamic end-to-end service. Resource utilization in load balancing is major concern in smart applications. Intelligent link prediction heuristic is used in the control plane for forwarding the data packets in the core network which enhances the performance of the network. Performance and different topologies are discussed in simulation setup and performance is represented with link prediction scheme.

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