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Retransmission Reduction using Checkpoint based Sub-Path Routing for Wireless IoT

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Abstract

Wireless IoT has been one of the major breakthroughs of the current decade. It has improved the quality of life and has also aided in several improvements in domains like healthcare. Effective routing and energy conservation has been the major challenges in creating and maintaining a successful IoT network. This work presents a checkpoint based routing model, CSPR, to improve the transmission efficiency by reducing retransmission. This work selects checkpoints in the network prior to transmission. The checkpoints are used to build the final path. This process ensures that the routes created are dynamic and reactive, leading to improved security and increased path reliability. Comparison with existing routing model shows improved network lifetime and reduced selection overhead levels, exhibiting the high efficiency of CSPR.

Keywords: Routing; Simulated Annealing; PSO; Checkpoint based Routing; Retransmission

1. Introduction

Internet of Things (IoT) connect billions of varied devices and aids in effective communication between the devices [1]. It strives to provide an integrated environment that helps in improving the quality of life of the users. The network is composed of heterogeneous devices, with each device collecting and processing a different type of information [2, 3]. Demand for IoT based networks are on the increase due to the ease of deployment and the varied conveniences offered by the network. Most of the devices in IoT networks are wirelessly connected and perform most of their transmissions through wireless communication [4]. Some devices are composed of high-level processing devices that can collect and process information effectively prior to transmitting it. However, most of the devices are used for information collection and transmission. This necessitates the need for effective routing techniques that can perform packet transfers with high efficiency [5].

Heterogeneity of devices proposes a huge challenge to the routing process. Other challenges include the network architecture, security requirements, reliable traffic management, effectiveness of the storage systems used etc. [6]. The network can sometimes be dynamic in nature resulting in failure of communication between the nodes. These unique challenges require novel routing requirements that can aid in reduced failures and successful packet transmissions. Existing routing protocols have been designed mostly for wired networks, or for homogeneous wireless networks [7, 8]. Hence, IoT networks require new protocols that can handle the challenges effectively. Further, resource utility is of very high significance in IoT networks. Available energy in the nodes has to be continuously monitored to ensure the node remains alive for further transmissions [9]. Managing the residual charge in an IoT device is a critical component to extend the network lifetime of the network. Load balancing is one of the most effective ways that can aid in extending the network lifetime [10]. Further reduction of retransmissions by applying effective routing protocols can also help in extending the network lifetime. The dynamicity of and IoT network increases the routing complexity [11].

This work presents reactive routing protocol that uses checkpoint based path identification model to ensure security and to provide in-demand dynamic paths. The routing model has been designed using metaheuristic algorithms to ensure faster route creation process. The initial phase identifies random checkpoints in the network. The second phase identifies routes between the checkpoints which are used by the nodes for data transfer. The multi level process ensures improved security during transmissions.

2. Related works

The route selection process plays a vital role in determining the efficacy of a network. This section presents some of the current and the most prominent works in the domain of route selection in wireless IoT.

A routing model that is based on state-action-reward-state-action (SARSA) to perform delay aware route selection has been proposed by Shi et al. [12]. This work is based on software defined networking which aids in configuring networks and managing them effectively. The model mainly focuses on improving the reliability of the transmission path and also aids in reducing transmission delay. A multipath routing technique that aids in providing congestion free traffic has been proposed by Adil [13]. This work mainly concentrates on providing multipath routing technique in an IoT environment. This work performs dynamic hop selection and uses a static routing protocol to perform load balancing. The architecture has been designed as a priority based communication infrastructure. A load balancing based routing model has been proposed by Talaat et al. [14]. This work performs dynamic resource allocation and uses reinforcement learning and genetic algorithms to create routes. Another similar load balancing based routing model has been proposed by Enokido et al. [15]. This model uses virtual machines for load distribution and to prolong the network lifetime. Other similar load balancing schemes include, a cloud-based load balancing model by RM et al. [16], and a multi hop routing model based on fuzzy clustering by Rajaram et al. [17].

A cluster-based routing algorithm for IoT has been proposed by Thangaramya et al. [18]. The technique concentrates on providing energy efficiency and reduces energy loss due to packet delivery failure. This work uses a neuro fuzzy rule to create clusters and performs cluster-based routing. A deep learning based model that uses reinforcement based techniques for routing in dynamic IoT networks has been proposed by Cong et al. [19]. This work has been designed and implemented as both centralized and distributed model. It has been identified by the centralized solution exhibits faster and better routing with high scalability levels. A similar work used for packet routing has been proposed by Xiao et al. [20]. A fuzzy logic based model for packet routing in IoT has been proposed by Garg et al. [21]. The work mainly concentrates on reducing packet loss to improve the routing performance. A metaheuristic routing model to ensure randomization in the routing process has been proposed by Upendran et al. [22].

Routing model concentrating on security has been proposed by Kothandaraman et al. [23]. This work proposes a sequence number based routing process that improves the security of the routing model. The model concentrates on maximizing the packet delivery ratio and also aims towards increasing the lifetime of the IoT network. A device-to-device strategy for routing has been proposed by Li et al. [24]. This work is based on the 5G architecture and aims to provide efficiency without the presence of 5G hardware. A multipath routing technique for wireless IoT has been proposed by Kim et al. [25]. This work uses a bridge node to ensure cooperation among the created paths. The work concentrates on detecting issues like transmission failures using the bridge nodes. Other reliability based routing models include multipath based models by Felemban et al. [26], Jung et al. [27] and Lee et al. [28].

3. Checkpoint based Sub-Path Routing (CSPR)

This contribution presents a metaheuristic based technique, Checkpoint based Sub-Path Routing (CSPR), that ensures reduction of retransmission and security in wireless IoT. The proposed contribution has been architected in three phases; the network initialization and search space creation phase; checkpoint determination and checkpoint based sub-path determination. Architecture flow of the CSPR model is shown in Figure 1.

3.1. Network Initialization and Search Space Creation

The nodes in IoT are deployed and are connected to form the network. The nodes transmit the initial hello packet, describing their status and their location information. The hello packet is transferred to all the nodes that are under the scope of the current node. This aids in building up of the network table containing details about all the available and reachable nodes. The process of search space creation is based on the network table. The nodes are considered to be static in nature. Hence the search space creation process is performed after network initialization. The search space is composed of nodes which depicts the IoT devices, and the connectivity between the nodes is represented by the edges in the graph. The constructed graph is used by the metaheuristic models for route identification.

3.2. Checkpoint Determination

Transmission initiation begins the route identification process. The routing process is performed in two phases; the first phase identifies intermediate checkpoints, while the second phase determines the actual routes. Randomized routing is performed to ensure that the routes cannot be pre-determined by the adversary. The routes are randomized; hence, every transmission request triggers a route creation process. This feature ensures that the routing algorithm cannot be exploited to identify the intermediate nodes. This section discusses the checkpointing based scheme for the routing process.

The checkpointing based routing model initially identifies random intermediate nodes that are used for the routing process. The identified nodes are added to the intermediate path. The nodes are dispersed around the network to ensure load balancing and security in the route creation process. Simulated Annealing is used as the model of choice for identifying the intermediate checkpoints. Simulated Annealing is a probabilistic technique that can be used to identify the global optimum solution for a function. It is considered to be highly effective on large search spaces and in problems requiring approximate global optimum solutions. Random near optimal nodes are selected for the path. These are the intermediate nodes that fall between the source node and the destination node.

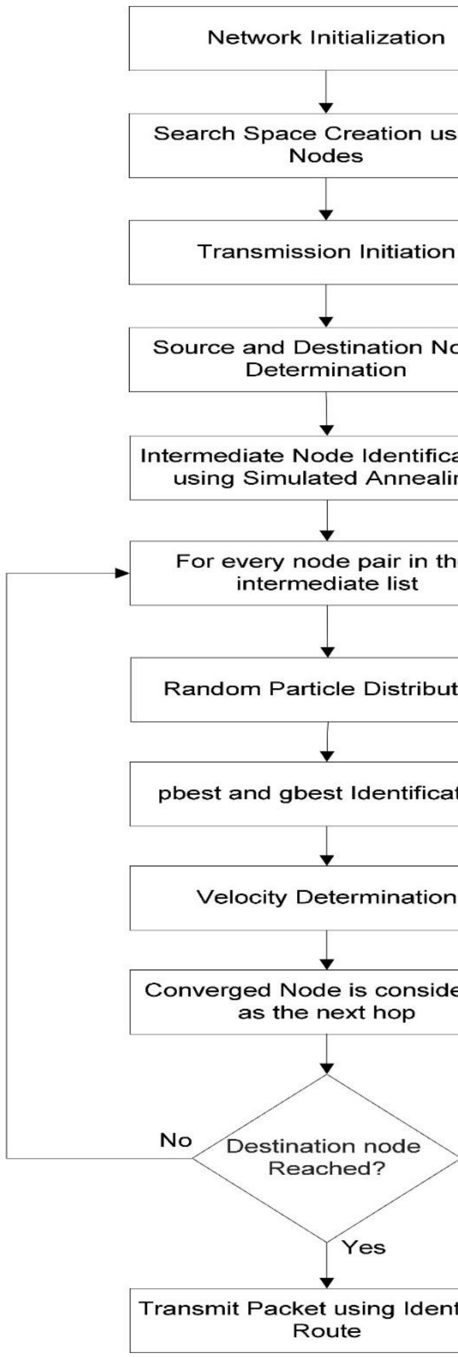

Figure 1: CSPR Architecture

3.3. Checkpoint based Sub-Path Determination

The sub-paths between the nodes needs to be determined to formulate the actual path. This process is performed in a reactive manner on the intermediate nodes. The source node is considered as the initiator. Modified PSO is used for the route identification process. The first intermediate node is considered as the sub-path destination. The particles are distributed in the search space, and the best sub-path identification process is initiated. The velocity component is initialized using the below equation,

$$V_i \sim U(-|b_{up} - b_{lo}|, |b_{up} - b_{lo}|)$$

Where b_{up} and b_{lo} refers to the upper and lower bounds in the search space.

The particle movement is triggered, and all the particles are made to move towards the optimal solution. Objective function, which is used as the base for node selection has been constructed based on the link quality, delivery delay and the remaining energy or charge contained in the node. The fitness between a source node *m* and the destination node *n* is given by,

$$fitness_{m,n} = \frac{quality_n * charge_n}{delay_n * dist_{m,n}}$$

Where $quality_n$ is the link quality, $charge_n$ is the charge of the node *n*, $delay_n$ is the expected delivery delay, and *dist* is the Euclidean distance between the source node *m* and the destination node *n*.

The *pbest* and *gbest* values are identified and the velocity equation in updated as,

$$V_{i,d} \leftarrow \omega V_{i,d} + \varphi_p r_p (P_{i,d} - X_{i,d}) + \varphi_g r_g (g_d - X_{i,d})$$

Where $P_{i,d}$ and g_d are the pbest and gbest values, r_p and r_g are random values, $x_{i,d}$ is the current position of a particle, and ω, φ_p, and φ_g represents the importance level of velocity, *pbest* and *gbest* values.

The process is repeated, and the particles are allowed to converge over a node, which is considered as the next hop. This process is repeated until the sub-path destination is reached. The obtained route is used for the transfer. After reaching the first intermediate node, it is considered as the source and the next intermediate node is considered as the sub-path destination. The PSO based route identification process is performed again and the data is routed via the obtained path. This process is repeated until the final destination node is reached.

4. Results and discussion

The CSPR model is validated by creating a network with 30 nodes and analyzing the performance based on the overhead levels and the distance covered for transmissions. The measurements were recorded for 100 transmissions and the average time and distance have been measured.

Selection overhead levels represent the time taken for the CSPR model to determine the path for packet transmission. The selection overhead levels for CSPR model have been measured and shown in figure 2. The model exhibits highest time requirement of 6ms and lowest of 1ms. Most of the overhead levels fall between 3ms and 4ms. The time requirements could be observed to be low, exhibiting the high efficiency of the selection process.

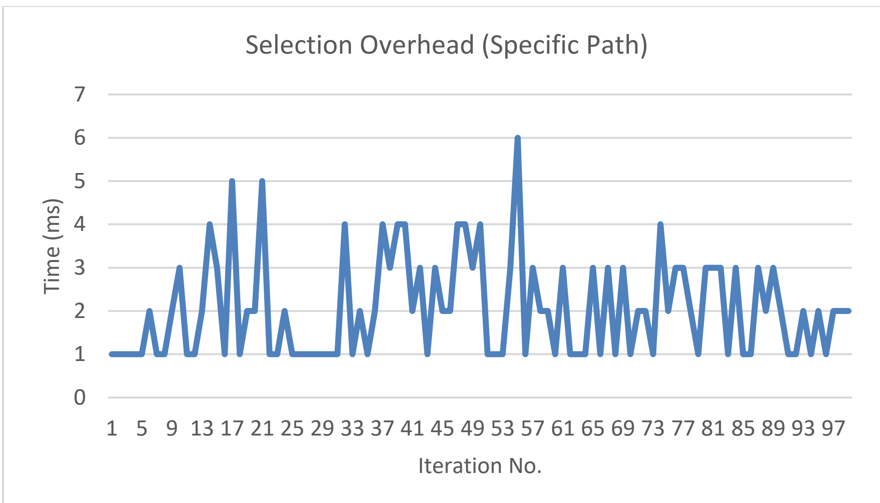

Figure 2: Selection Overhead of CSPR

Distance covered during transmissions have been measured and shown in figure 3. Distance covered reaches a maximum level of 300, while most of the measured distances fall below 200. Lower distances represent better routing process. However, this leads to frequent usage of nodes at critical points in the network. As the CSPR model incorporates load balancing into the routing process, slight increase in distance levels is expected.

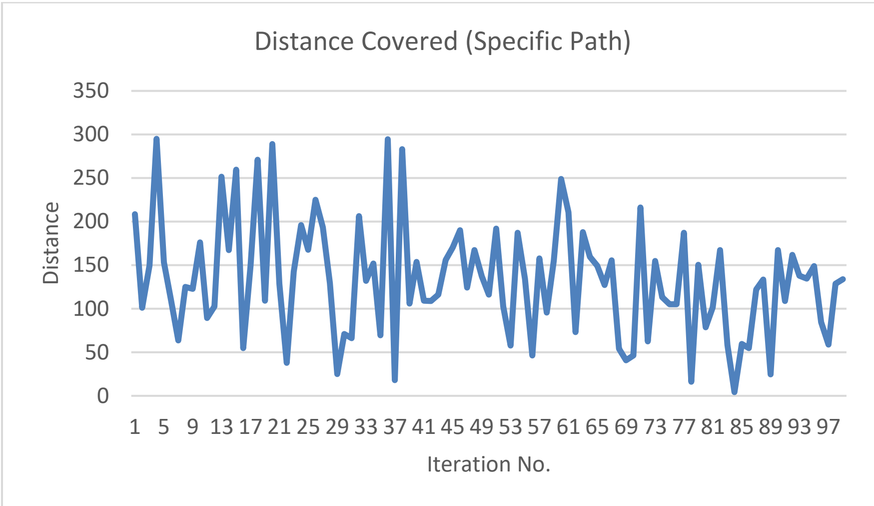

Figure 3: Distance Covered by CSPR

A comparison of the average path length of CSPR and RR-PSO [22] is shown in figure 4. Although load balancing has been imposed in CSPR, it could be observed that the CSPR model exhibits lower path length exhibiting the high efficiency of the route identification process.

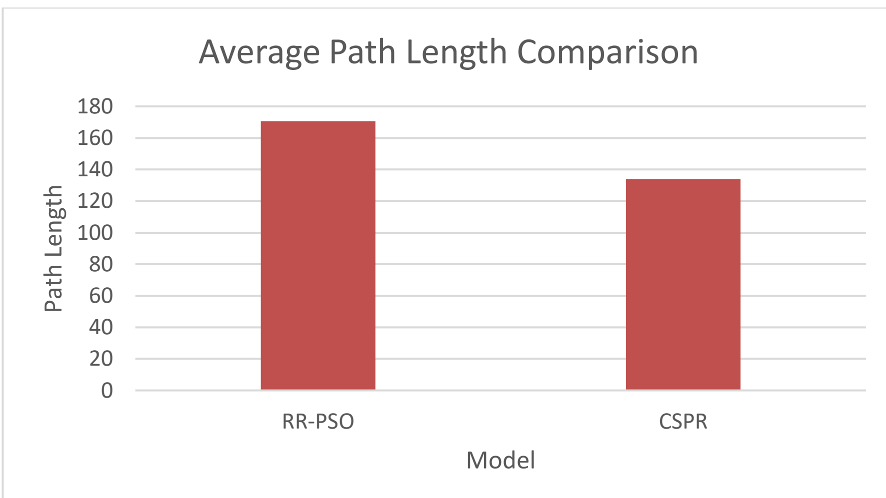

Figure 4: Average Path Length Comparison of CSPR

Node usage levels of CSPR has been compared with RR-PSO [22] and presented in figure 5. Balanced usage levels are expected in effective models exhibiting load balancing. The RR-PSO model exhibits high fluctuation levels in the usage of nodes, resulting in high peaks and troughs. The usage graph of CSPR could be observed to exhibit low variations, depicting equal overall usage levels of the nodes. This ensures that the network is stable and also improves the network lifetime.

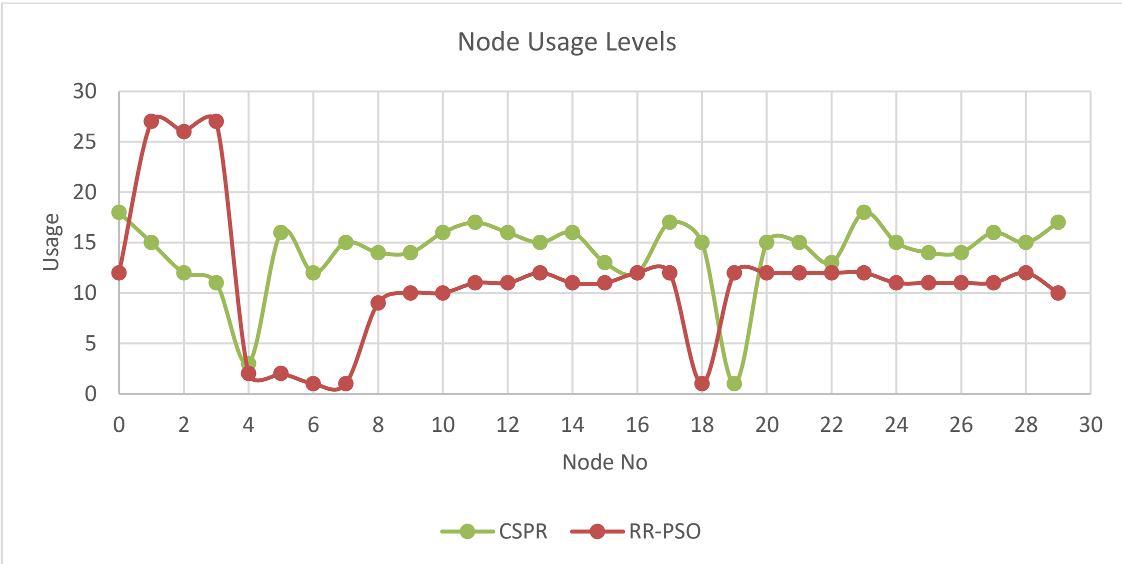

Figure 5: Comparison of Node Usage Levels of CSPR

5. Conclusion

Routing in wireless IoT exhibits specialized challenges due to the dynamic nature of the network. This work presents a checkpoint based routing model, CSPR, that enables improved routing. The routing process involved initial identification of checkpoints, followed by creating sub-paths to connect the checkpoints. This two-level routing process ensures that the paths identified are dynamic in nature, resulting in improved security. Sniffing attack and sinkhole attacks can be effectively avoided. Further, the reactive routing process ensures reduced retransmission levels. The checkpoint paths are short and hence result in reduced overheads. Although load balancing has been effectively achieved, node usage levels still exhibit small fluctuation levels which could be reduced in further works.

6. References

[1]. K.-F. Hsu, R. Beckett, A. Chen, J. Rexford, D. Walker, Contra: A programmable system for performance-aware routing, in: 17th {USENIX} Symposium on Networked Systems Design and Implementation ({NSDI} 20), 2020, pp. 701-721.

[2]. S.K. Dhurandher, J. Singh, M.S. Obaidat, I. Woungang, S. Srivastava, J.J. Rodrigues, Reinforcement learning-based routing protocol for opportunistic networks, in: ICC 2020-2020 IEEE International Conference on Communications (ICC), IEEE, 2020, pp. 1-6. https://doi.org/10.1109/ICC40277.2020.9149039

[3]. D. Zhang, H. Ge, T. Zhang, Y.-Y. Cui, X. Liu, G. Mao, New multi-hop clustering algorithm for vehicular ad hoc networks, IEEE Trans. Intell. Transp. Syst. 20 (4) (2019) 1517-1530, http://dx.doi.org/10.1109/TITS.2018.2853165.

[4]. D.-G. Zhang, C. Gong, T. Zhang, J. Zhang, M. Piao, A new algorithm of clustering AODV based on edge computing strategy in IOV, Wirel. Netw. 27 (2021) 2891-2908, http://dx.doi.org/10.1007/s11276-021-02624-z.

[5]. M. Centenaro, L. Vangelista, A. Zanella, M. Zorzi, 'Long-range communications in unlicensed bands: The rising stars in the IoT and smart city scenarios, IEEE Wirel. Commun. 23 (5) (2016) 60-67. https://doi.org/10.1109/MWC.2016.7721743

[6]. I. Ud Din , M. Guizani , S. Hassan , B. Kim , M. Khurram Khan , M. Atiquzzaman , S.H. Ahmed , The internet of things: a review of enabled technologies and fu- ture challenges, IEEE Access 7 (2019) 7606-7640. https://doi.org/10.1109/ACCESS.2018.2886601

[7]. K. Jaiswal , V. Anand , Eomr: an energy-efficient optimal multi-path routing pro- tocol to improve qos in wireless sensor network for IoT applications, Wirel. Pers. Commun. (2019) 1-23. https://doi.org/10.1007/s11277-019-07000-x

[8]. Z. Wang , X. Qin , B. Liu , An energy-efficient clustering routing algorithm for WSN-assisted IoT, in: 2018 IEEE Wireless Communications and Networking Conference (WCNC), 2018, pp. 1-6. https://doi.org/10.1109/WCNC.2018.8377171

[9]. WSN Data Collection and Routing Protocol with Time Synchronization in Low-cost IoT Environment

[10]. NESEPRIN: A new scheme for energy-efficient permutation routing in IoT networks

[11]. A survey on energy efficient routing techniques in wsns focusing IoT applications and enhancing fog computing paradigm

[12]. SARSA-based delay-aware route selection for SDN-enabled wireless-PLC power distribution IoT

[13]. Congestion free opportunistic multipath routing load balancing scheme for Internet of Things (iot)

[14]. Talaat, F. M., Saraya, M. S., Saleh, A. I., Ali, H. A., & Ali, S. H. (2020). A load balancing and optimization strategy (LBOS) using reinforcement learning in fog computing environment. Journal of Ambient Intelligence and Humanized Computing, 1-16. https://doi.org/10.1007/s12652-020-01768-8

[15]. Enokido, T., & Takizawa, M. (2020). The Redundant Energy Consumption Laxity Based Algorithm to Perform Computation Processes for IoT Services. Internet of Things, 9, 100165. https://doi.org/10.1016/j.iot.2020.100165

[16]. RM, S. P., Bhattacharya, S., Maddikunta, P. K. R., Somayaji, S. R. K., Lakshmanna, K., Kaluri, R., ... & Gadekallu, T. R. (2020). Load balancing of energy cloud using wind driven and firefly algorithms in internet of everything. Journal of Parallel and Distributed Computing.

[17]. Rajaram, V., & Kumaratharan, N. (2020). Multi-hop optimized routing algorithm and load balanced fuzzy clustering in wireless sensor networks. Journal of Ambient

Intelligence and Humanized Computing, 1-9. https://doi.org/10.1007/s12652-020-01827-0
[18]. Energy Aware Cluster and Neuro-Fuzzy Based Routing Algorithm for Wireless Sensor Networks in IoT
[19]. A deep reinforcement learning-based multi-optimality routing scheme for dynamic IoT networks
[20]. S. Xiao, H. Mao, B. Wu, W. Liu, F. Li, Neural packet routing, in: Proceedings of the Workshop on Network Meets AI & ML, 2020, pp. 28-34. https://doi.org/10.1145/3405671.3405813
[21]. Applying machine learning in IoT to build intelligent system for packet routing system
[22]. Secure and Distributed On-Demand Randomized Routing in WSN
[23]. Sequence number based secure routing algorithm for IoT networks
[24]. D2D routing aided networking for efficient energy consumption management of wireless IoT
[25]. Cooperative multipath routing with path bridging in wireless sensor network toward IoTs service
[26]. E. Felemban , C.-G. Lee , E. Ekici , MMSPEED: multipath multi-speed protocol for qos guarantee of reliability and timeliness in wireless sensor networks, IEEE Trans. Mob. Comput. 5 (2006) 738-754. https://doi.org/10.1109/TMC.2006.79
[27]. K. Jung , E. Lee , S. Oh , Y. Yim , S. Kim , Localized disjoint multipath routing protocol in irregular wireless sensor networks, in: 2013 IEEE 24th Annual Inter- national Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC), 2013, pp. 2454-2458.
[28]. J. Lee , H. Park , S. Oh , Y. Yim , S. Kim , Radio-disjoint geographic multipath routing for reliable data transfer in lossy wsns, in: Proc. IEEE 75th Vehicular Tech- nology Conf. (VTC Spring), 2012, pp. 1-5. https://doi.org/10.1109/VETECS.2012.6240296