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Resilient Energy-Efficient Service Embedding in Smart Buildings with Latency Minimization

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Abstract*:* *This paper introduces a generic MILP model that has been developed to minimizethepowerconsumptionduetobothprocessingandthetrafficflowthrough the network to minimize the end to end data delivery time with resilient embedding. We investigate various resilience schemes for IoT nodes and traffic and evaluate the performance and the implications of these schemes in smart building settings, such as the data delivery time and energy consumption. We formulate the problem of finding the optimal set of IoT nodes and links to embed BPs into the IoT layer as an optimization problem, with an objective function that aims to minimize both the total power consumption and the traffic latency.*

Keywords: Resilient service embedding, IoT Networks, MILP

I. INTRODUCTION

The IoT concept unlocks an uncountable number of services which include smart home solutions and industrial and public utility automation. The continuous expansion of these IoT deployments creates an urgent problem for developers to determine robust methods for their construction. The IoT nodes experience potential failure risks from unexpected breakdowns combined with attacks including various damages and unreliable wireless connections and reduced transmission power capabilities and limited computing efficiency and storage capacity. Part of the Internet of Things involves multiple heterogeneous devices that establish Internet connections. The main routing mechanism for IoT networks depends on Routing Protocol for Low-Power and Lossy Networks (RPL). The RPL protocol has been specifically developed to select one particular path between source and destination nodes [1]. RPL performs as an energy-efficient protocol but affects network service performance through node fault occurrences and dropped links caused by power saving or changes in network connectivity and attack vulnerabilities[2].

This section presents a generic MILP model which addresses power consumption resulting from network traffic together with processing demands for enhancing end-to-end data delivery time resilience. A thorough analysis of IoT node and traffic resilience models takes place to study their performance consequences within smart building environments through time-based data delivery measurements and energy utilization assessments. This work presents the optimization problem of determining optimal IoT nodes and links for implementing BPs by developing an objective function that reduces power consumption and traffic latency.

II. PROPOSED ARCHITECTURE

A framework which improves service resilience was developed for Internet of Things networks operating in the smart building environment introduced. The system builds networks while maintaining sufficient fault-tolerance standards and enables failure recovery after node or link breakdowns.

The probabilistic approach underpinning our framework states that k-connectivity of networks means the network continues to connect its nodes when any single node or link is taken out from the network. The proposed framework establishes recovery levels for each possible system failure that includes sensor breakdowns as well as controller outages and link failures. The evaluation of proposed resilience levels focused on their impact on end-to-end service delay together with energy consumption levels. There exist three resilience levels for evaluation:

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2.1. Resilient service embedding with nod eco existence constraint.

The service embedding with coexistence constraint represents the starting point for resilience implementation. This scheme functions as the original defense system against potential temporary network issues including data collisions and packet drops.

The resilience scheme operates using one path between the source and destination nodes ensuring the source node has insurance for recovering lost packets through repeated transmissions until receiving confirmation from the destination node. The disadvantage of this scheme includes increased transmission overhead that results in poor effects on unreliable data transmission and high network congestion.

2.2. Resilient service embedding with sensor–actuatornode redundancy.

The resilience of IoT networks can be enhanced through an additional proposed solution. Another solution introduces additional nodes and links to form backups for sensor and actuator points. Chiagbeil's redundancy scheme strengthens the infrastructure resistances to service failure along with disruptive attacks. Scientists analyzed partial redundant component architectures to research how supplementary nodes and links function as reliabilities to improve service operation performance. Our analysis included both redundant actuating and sensing nodes because of their impact on accuracy and data integrity as well as system resilience.

2.3. Resilient service embedding with all-noderedundancy.

Several public service domains require resilience as an essential quality such as fire protection and security services operating in buildings. The non-significant cost of service components such as nodes and energy consumption allows the implementation of a feasible new scheme that adds redundant components to every node to provide end-to-end multi-path routing capabilities.

2.4. Resilient service embedding with traffic redundancy.

This service involves creating different communication paths linking source to destination nodes for traffic resilience purposes. In this configuration the main path functions as the primary network route for traffic transmission between nodes but backup routes operate as alternative paths for backup functions. The backup paths automatically activate in case of primary path failure through active 'Keep-alive' data transmission. The intermediate node activates two processes when the primary path fails: it both returns data packets to the source node while also notifying the destination node about the path failure. After the path failure the routing table becomes updated by the source along with the destination nodes so they choose new routing alternatives.

2.5. Resilient service embedding with traffic replication.

The traffic resilience requirement is achieved through this scheme by transmitting multiple data duplicates over multiple selected paths between source and destination nodes. This technique supports high packet delivery rates together with short delivery times without requiring communication for state updating between source and destination nodes because destination nodes obtain lost packets from other packet copies. Replication attains high resistance against failures yet consumes considerable energy because of network traffic at each node.

2.6. Resilient service embedding with traffic splitting.

The proposed method involves dividing traffic between two paths that lead from the source node to the destination node with each path receiving data splits worth 50% of the overall traffic while keeping 'Keep-alive' traffic on the same path until a path failure occurs then the source node automatically sends undelivered data which stays below 50% of the original data through the functioning path to save delivery time and conserve energy. The splitting rate was established at 50% to 50% because we assumed uniform reliability across network links which granted each link similar priority to data transfer. The braided multipath method should be integrated in our framework because alternative nodes use primary path node coverage areas to prevent service interruptions.

III. FRAMEWORK OF RESILIENT ENERGY-EFFICIENT SERVICE EMBEDDING IN IOT NETWORKS

The following subsection describes the service embedding framework built for IoT networks. The framework applies an MILP optimization model that minimizes total energy usage along with service embedding traffic latency in IoT networks and maintains optimal node and traffic resilience.

3.1.Splitting-based schemes

In this section, we propose a traffic splitting-based resilience scheme through the multiple paths concept to reduce the arrival rates through the intermediate nodes; doing so will consequently minimise the delivery time, in addition to enhancing the resilience of the IoT network.

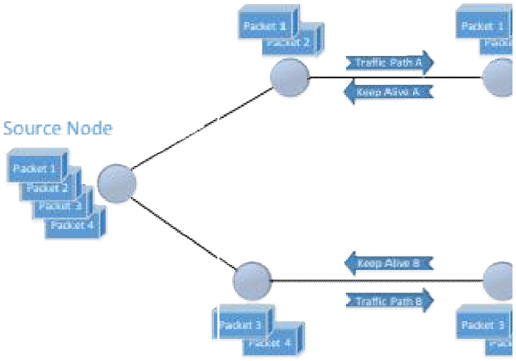

Figure 1: Traffic Splitting Scheme

The proposed framework splits the traffic between the source node splits and routes it into two paths (A and B), as shown in Figure1. The source node sends one half of the traffic through path A and the other half through path B to the destination node, and the source node receives a 'Keep-alive' signal continuously from both paths (A and B). Once a failure occurs on one path, the source will not receive an acknowledgement from this path and will then switch the traffic to another path.

Let us suppose that the source node has 100 packets to send to the destination node. The source node will select two paths and send 50 packets on each path to the destination node. In a probabilistic scenario in which one link has failed on the network, the source node will resend only 50 packets or less rather than resending all 100 packets as in retransmission.

IV. RESULTS AND EVALUATION

The smart building enterprise or university campus physical layer consists of 30 IoT nodes interconnected through 89 wireless links to evaluate the performance of our proposed model. These IoT nodes spread across 500 m × 500 m campus area according to description. The measure of power usage and mean traffic delay served as indicators for evaluation when embedding resilient services through different zones under coexistence conditions. The model adopted the described objective function to conduct energy efficient-low latency service embedding. The model relies on k-connected nodes to ensure network recovery after link or node failures during the failure recovery phase. We implement our model with both resilience plan sets.

4.1. Energy-efficient low-latency node-resilient service embedding

For the node-resilient scheme, we run three resilience levels with the objective of minimizing the total power consumption and the mean traffic latency:

- Coexistence constraint node resilience(CCNR)
- Partial redundancy node resilience(PRNR)
- Full redundancy node resilience (FRNR)

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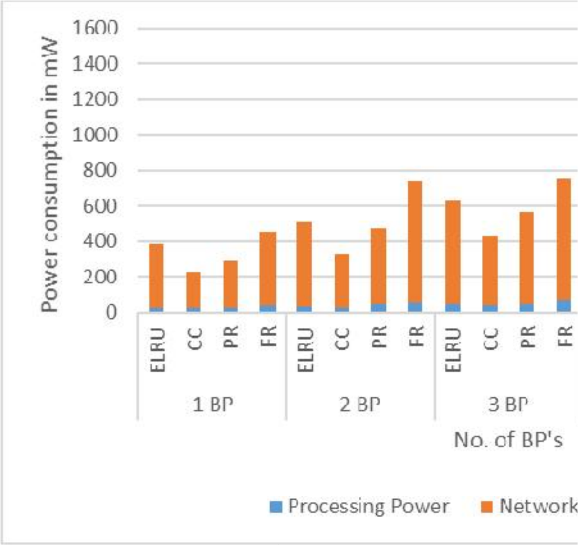

Figure2:Powerconsumptionofenergy-efficientlow-latencynode-resilientserviceembedding.

In Figure 2 the combined power consumption data shows CCNR as the lowest consumer followed by PRNR then FRNR and ELRU as the highest power-consuming scenario. The average power use of CCNR exceeds ELRU by 35% according to the presented results. The PRNR power consumption level exceeds that of ELRU by 10%.

The power consumption of the FRNR scenario exceeds the other scenarios thus resulting in 40% more power usage than the ELRU scenario.

Each scenario increases power consumption because redundant nodes get embedded along with their related traffic yet the IoT network maintains efficient service provision when a single node fails because of improved resilience.

4.2. Energy-efficient low-latency traffic-resilient service embedding

The traffic-resilient scheme contains three resilience levels to achieve minimum power consumption along with minimal traffic mean latency.

- Redundancy-basedtrafficresilience(RDTR)
- Replication-basedtrafficresilience(RPTR)
- Splitting-basedtrafficresilience(STR)

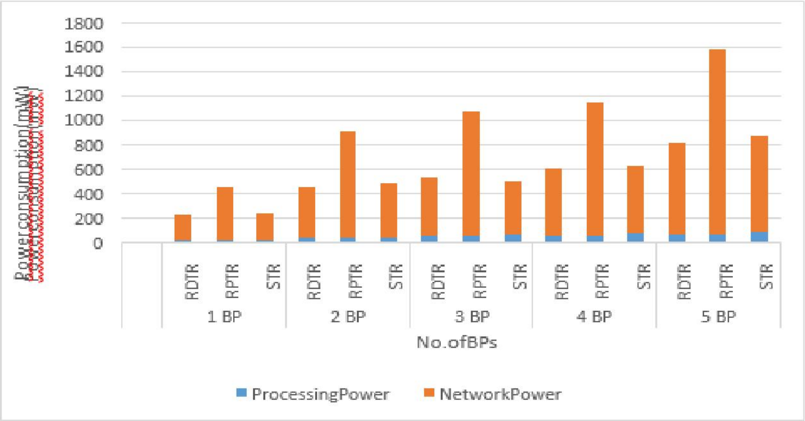

Figure3:Power consumption of traffic-resilient service embedding scenariosWithout failure.

The presented Figure 3 demonstrates how the traffic- resilient service embedding affects power consumption among RDTR, RPTR, and STR options in packet delivery conditions without network failures. The RDTR service consumed the least power while generating an average 47% power reduction compared to RPTR and a 4% reduction from STR scenarios. The power consumption of STR surpasses that of RDTR when three BPs are embedded due to its capability to optimize energy-efficient routes for traffic portions (50%) than applying the whole flow to one single energy-efficient path.

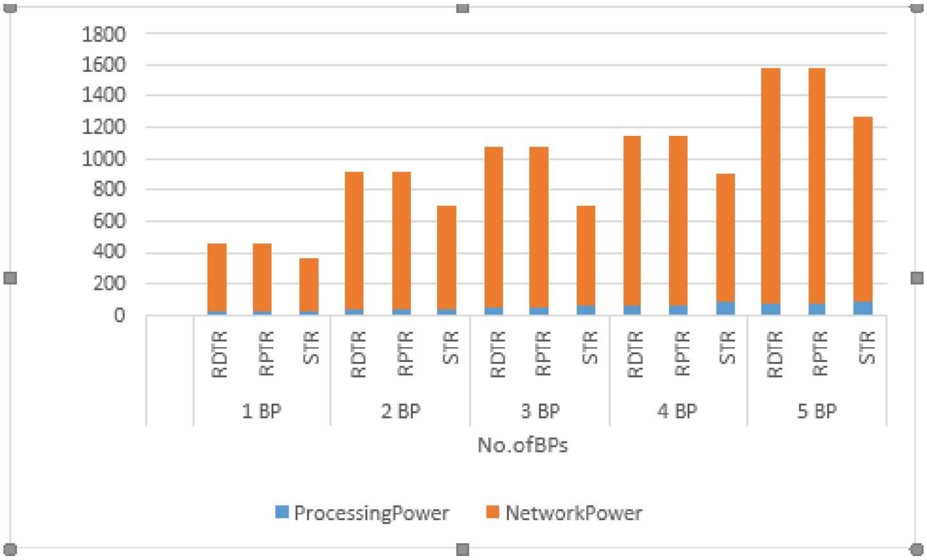

Figure4:Power consumption of traffic-resilient service embedding scenarios withfailure.

The research shows that traffic- resilient service embedding requires different power amounts for RDTR, RPTR, and STR under one-link failure conditions within the packet delivery setup (Figure 6-4). The data retransmission via the secondary path causes RDTR to use the same amount of power that RPTR uses. The STR provides an average power efficiency level of 25% better than the RDTR implementation approach.

A power saving of 25% occurs in the case of link failure when using the proposed technique in the STR scenario but this approach requires 4% more power for successful data delivery.

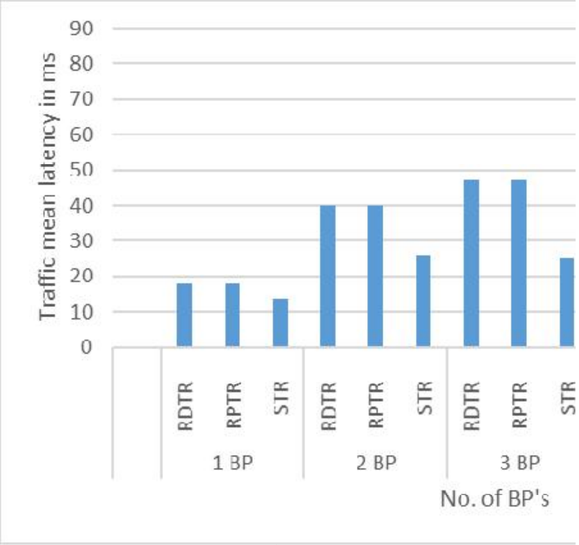

Figure5:The traffic resilient service embedding scenarios demonstrate their average delivery delay throughout the system.

The presented graph Figure 4 illustrates power usage for traffic- resilient service embedding which evaluates RDTR and RPTR as well as STR identification under one link failure condition. The data retransmission mechanism that uses the secondary path makes RDTR deliver equal power consumption figures as RPTR. The STR achieves an average power saving of 25% while compared against the operation of RDTR.

The power usage during STP success reaches 4% higher than the proposed approach but demonstrates 25% lower power expenditure when faced with one broken link.

Figure 6 indicates how total power usage changes between RDTR and STR methods at multiple PDR values[237]. The RDTR proves to be an energy-saving method which enables high-performing networks to achieve PDR greater than 95%. Higher power savings emerge from the STR scenario yet it reveals lower PDR. An increase in power efficiency of 10% occurs when comparing the STR to RDTR under PDR = 70% condition. This data allows researchers to compare how much power the RDTR consumes next to the STR without RPTR since RPTR maintains the highest power use throughout all situations.

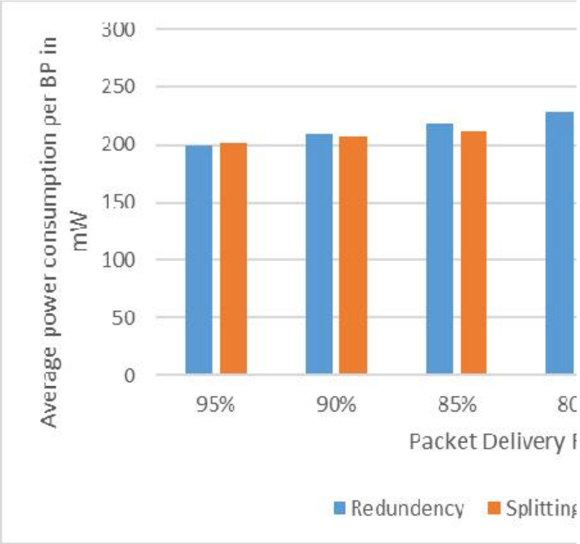

Figure6:Power consumption of traffic-resilient service embedding scenarios
For different PDR scenarios.

V. CONCLUSION:

A review of IoT network resilience schemes including node and traffic resilience levels at multiple levels appeared in this chapter. The authors built a MILP model for increasing service system resilience levels. The proposed scheme together with the developed model allowed both node readiness and traffic reliability enhancement leading to the development of an energy-efficient low-latency resilient service for smart buildings. Researchers developed different node and traffic resilience levels which allowed performance analysis between mean traffic latency and power consumption measurements. The research introduced traffic splitting as a new method which enhances network performance together with resilience levels by shortening packet delivery times. A study examined the splitting techniques with investigation into their redundancy aspects. Replication resilience techniques in terms of the total power consumption and the mean traffic latency for different values of PDR.

Power-saving reached 10% when the STR approach was compared to the RDTR method at PDR set to 70%. Average mean traffic latency became reduced by 37% when the STR was implemented instead of RDTR and RPTR. STR reduced the mean traffic latency through traffic splitting techniques which led to decreased node arrival rate. The traffic splitting method delivered superior performance markers through reduced end-to-end delays.

REFERENCES

[1] K. A. Foster, "A case study approachto understanding regional resilience," 2007.

[2] C. Del-Valle-Soto, C. Mex-Perera, R. Monroy, and J. Nolazco-Flores, "On the routing protocol influence on the resilience of wireless sensor networks to jamming attacks," Sensors, vol. 15, no. 4, pp. 7619-7649, 2015.

[3] H. Lamaazi, N. Benamar, and A. J. Jara, "RPL-based networks in static and mobile environment: A performance assessment analysis," Journal of King Saud University- ComputerandInformationSciences, vol. 30, no.3, pp. 320- 333, 2018.

[4] M. Condoluci, G. Araniti, T. Mahmoodi, and M. Dohler, "Enabling the IoT machine age with 5G: Machine-type multicast services for innovative real-time applications," IEEE Access, vol. 4, pp. 5555-5569, 2016.

[5] P. R. Adki and J. Agarkhed, "Cloud assisted time-efficient vehicle parking services," in 2016 International Conference on Inventive Computation Technologies (ICICT), 2016, vol. 1: IEEE, pp. 1-7.

[6] X. Dong, T. E. El-Gorashi, and J. M. Elmirghani, "On the energy efficiency of physical topology design for IP over WDM networks," Journal of Lightwave Technology, vol. 30, no. 11, pp. 1694-1705, 2012.

[7] M. Musa, T. Elgorashi, J. Elmirghani, and Networking, "Energy efficient survivable IP-over-WDM networks with network coding," Journal of Optical Communications, vol. 9, no. 3, pp. 207-217, 2017.

[8] X. Dong, T. El-Gorashi, and J. M. Elmirghani, "IP overWDM networks employing renewable energy sources," Journal of Lightwave Technology, vol. 29, no. 1, pp. 3-14, 2011.

[9] M. S. Hadi, A. Q. Lawey, T. E. El-Gorashi, and J. Elmirghani, "Patient-Centric Cellular Networks Optimization using Big Data Analytics," 2018.

[10] H. M. M. Ali, T. E. El-Gorashi, A. Q. Lawey, and J. M. Elmirghani, "Future energy efficient data centers with disaggregated servers," Journal of Lightwave Technology, vol. 35, no. 24, pp. 5361-5380, 2017.

[11] C. Gray, R. Ayre, K. Hinton, and R. S. Tucker, "Power consumption of IoT access network technologies," in 2015 IEEE International Conference on Communication Workshop (ICCW), 2015: IEEE, pp. 2818-2823

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