Grid-based Model for Recovery of Lost Connectivity in Wireless Sensor and Actor Network

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Introduction

Wireless Sensor and Actor Networks (WSAN) are basically a collection of actors and sensors collaborating via a wireless medium to perform designated tasks. Maintaining inter-actor connectivity is critical to a WSAN, as failure at one point may result in communication loss amongst nodes or in a network disjoint. To recover from an actor node failure, optimal re-localization and coordination techniques should be in place. However, existing recovery schemes suffer from high degrees of actor node relocation overhead as well as network overhead. In this paper, we introduce a Grid-based Mathematical Model for efficient Actor Recovery by Determining Forwarding Capacity (GMMFC). The proposed model aims to provide effective monitoring and actor failure detection mechanism supported by an efficient actor recovery algorithm. GMMFC presents an innovative concept in actor node recovery while proposing improvements in WSAN QoS performance using RSSI Message information. The proposed solution is compared with state-of-the-art algorithms. The experimental results manifest better performance over delay, throughput, packet delivery ratio, energy consumption as well as for messages exchanged between sensor and actor nodes. Thus, the proposed model demonstrates improvements in QoS parameters.

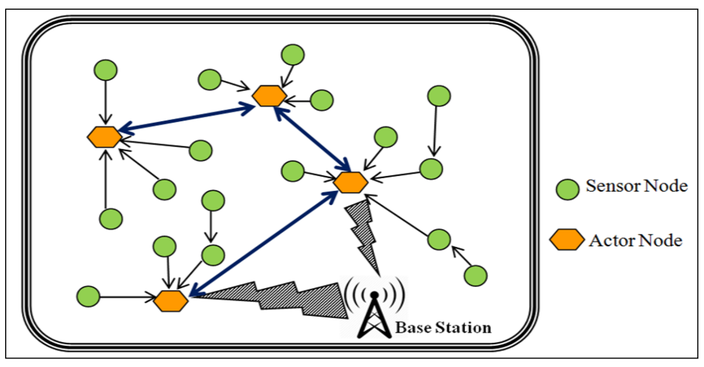

Figure 1. WSAN

Grid-based Model for Efficient Actor Recovery (GMMFC)

- Grid-based.
- Grid is split into 9 cells.
- Each cell contains two positioning points.
- Mobile actor nodes.
- Static sensor nodes.
- Base station.

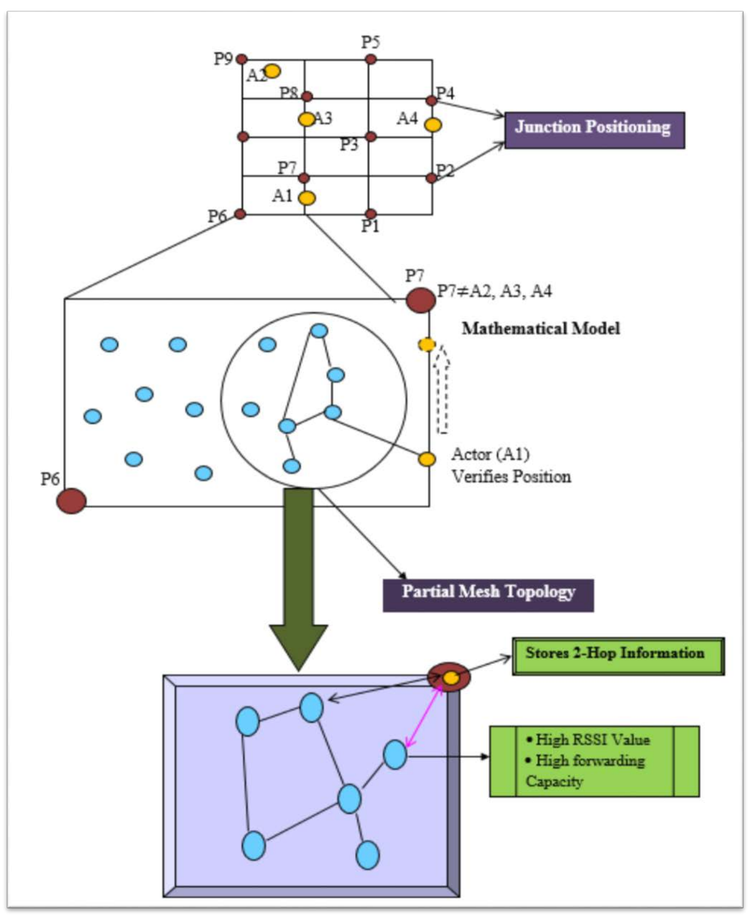

Figure 2. GMMFC Architecture

Cell Architecture

- Random deployment actor nodes.
- Sensor nodes are deployed in partial mesh topology.
- Best candidate actors are chosen to allocate the positioning points.

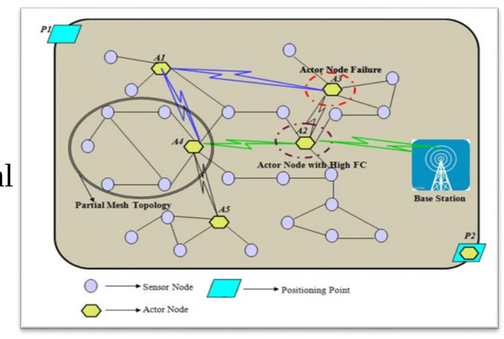

Figure 3. Cell Architecture

Mathematical Model

Let us assume that Matrix 'F' involves set of RSSI vectors. Each neighbor hears the RSSI vectors that is represented as,

$$F = \{F_1, F_2, F_3, \ldots, F_n\}^N \qquad (1)$$

We apply linear function to describe the relationship between RSSI and transmission power on a pair-wise basis.

$$f_j(\Delta p_l) = a_j \times \Delta p_l + b_j \qquad (2)$$

We further apply the least square approximation formulation. The sample forwarding capacity of the actor is represented as follows s F_c:

$$F_c = \sum_j^{\infty} f_j(\Delta p_l) - F_j^k))^2 \qquad (3)$$

As per the changes in power intensities, RSSI values will also vary and so this is a significant parameter.
Thus,
a_j and b_j can be determined as

$$\begin{vmatrix} a_j \\ b_j \end{vmatrix} = \frac{1}{N(\sum_{k=0}^{M}(\Delta p_l)^2 - \sum_{k=0}^{M}(\Delta p_l)^2)} \times \left[\sum_{k=0}^{M} F_j^k \sum_{k=0}^{M}(\Delta p_l)^2 - \sum_{k=0}^{M}(\Delta p_l) \times \sum_{k=0}^{M}(\Delta p_l) \times F_j^k \; N \; \sum_{k=0}^{M}(\Delta p_l) \times F_j^k - \sum_{k=0}^{M}(\Delta p_l) \sum_{k=0}^{M} F_j^k\right] \qquad (4)$$

Equation (4) shows an initial model that is used to determine the actor's forwarding capacity.

Junction Positioning Mechanism

- In case of actor failure, positioning point will handle managing the recovery process.

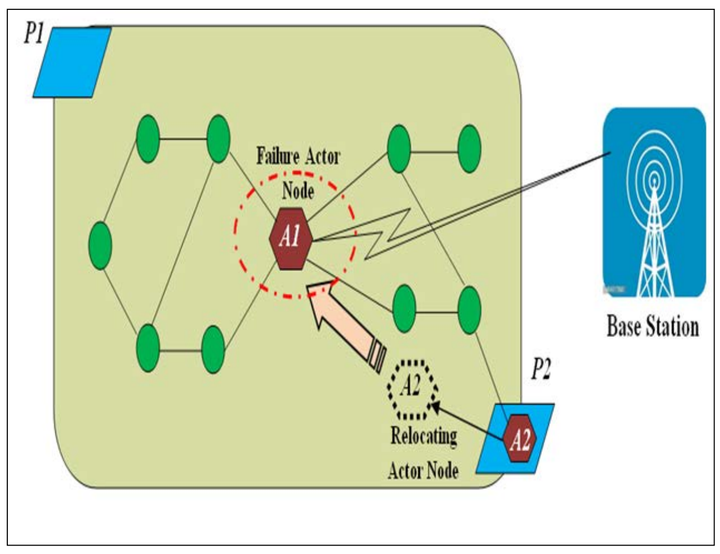

Figure 4. Actor failure and positioning points

Simulation Setup

- OMNET Simulator
- Fixed position sensors
- Mobile actors

Parameters	Values / Ranges
Field Size	1000 × 1000 m
Number of Grid Region	Nine
Number of Sensor Nodes	30 - 50
Number of Actor Nodes	5 – 15
Bit Rate	2 – 60 mbps
Transmission Range	100m
Mobility Speed	10 – 100 m/sec

Table 1. Simulation Parameters

Results

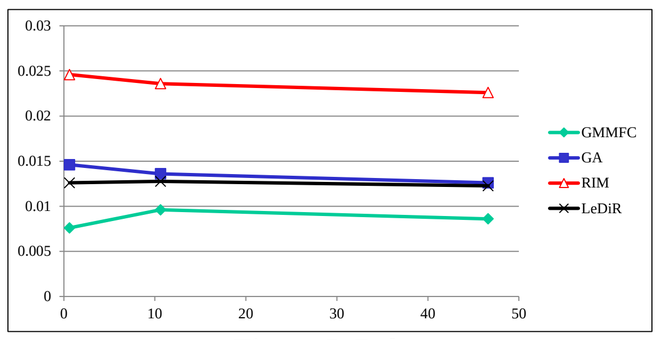

Figure 5. Delay

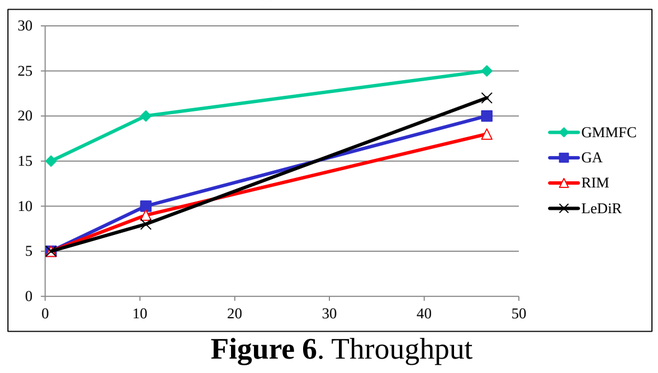

Figure 6. Throughput

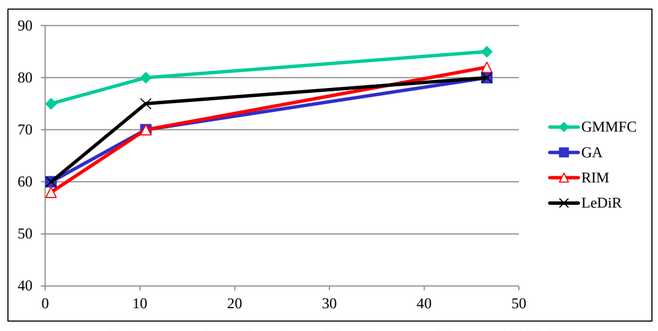

Figure 7. Packet Delivery Rate (PDR)

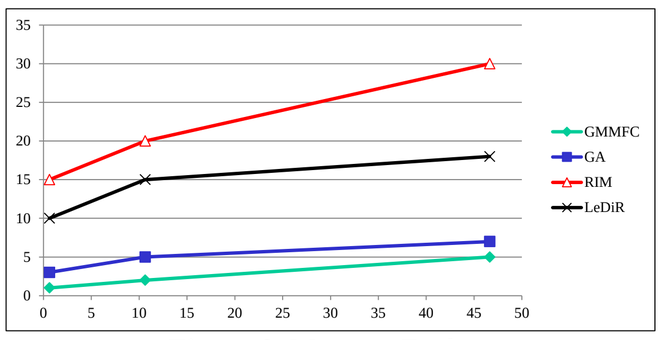

Figure 8. Message Exchange

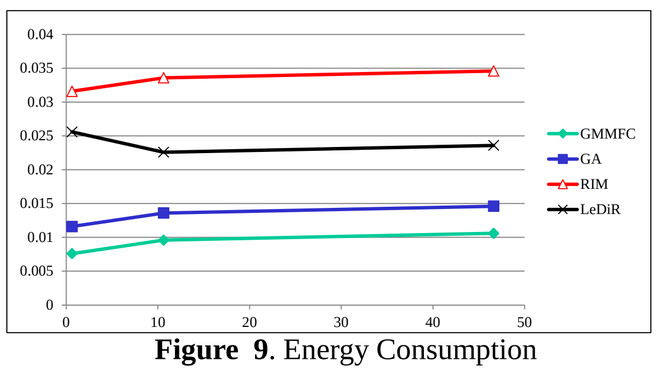

Figure 9. Energy Consumption

Parameter Algorithm	Delay	Throughput	Path Length Validation
GMMFC	Low	High	Excellent
GA [1]	High	Medium	Low
RIM [2]	High	Medium	Poor
LeDiR [3]	Medium	Medium	Good

Table 2. Comparison of Node Recovery Techniques

Conclusions

A Grid-based Model for efficient Actor Recovery by Determining Actor Forwarding Capacity is proposed. The major contributions include;

- Introducing GMMFC actor detection and recovery algorithm.
- Introducing a junction Positioning Mechanism.
- Determination of Actor Forwarding capacity with the support of RSSI value by using proposed Mathematical Model.
- Improving backup node selection, and using contention-free RSSI for predicting the actor's Forwarding Capacity
- The results manifest better performance over delay, throughput, packet delivery ratio, energy consumption as well as for messages exchanged between sensor and actor nodes.

References
[1] Ranga, V.; Dave, M.; Verma, A.K. Recovery of lost connectivity in wireless sensor and actor networks using static sensors as bridge routers. *Procedia Computer Science* 2015, *70*, 491-498.
[2] M. Younis, S. Lee and A. A. Abbasi, "A Localized Algorithm for Restoring Internode Connectivity in Networks of Moveable Sensors," in *IEEE Transactions on Computers*, vol. 59, no. 12, pp. 1669-1682, Dec. 2010.
[3] Abbasi, A.A.; Younis, M.F.; Baroudi, U.A. Recovering from a node failure in wireless sensor-actor networks with minimal topology changes. *Vehicular Technology, IEEE Transactions on* 2013, *62*, 256-271.