

Trust-aware Routing Protocol for Mobile Crowdsensing Environments

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(Invited Paper)

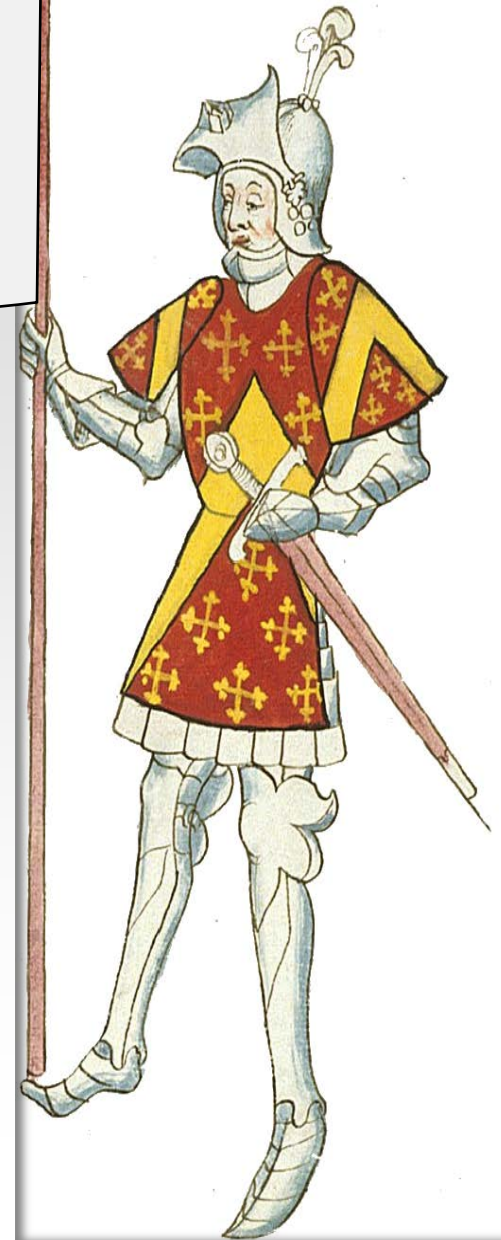
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Abstract—Link quality, trust management and energy efficiency are considered as main factors that affect the performance and lifetime of Mobile CrowdSensing (MCS). Routing packets toward the sink node can be a daunting task if aforementioned factors are considered. Correspondingly, routing packets by considering only shortest path or residual energy lead to suboptimal data forwarding. To this end, we propose a Fuzzy logic based Routing (FR) solution that incorporates social behaviour of human beings, link quality, and node quality to make the optimal routing deci-

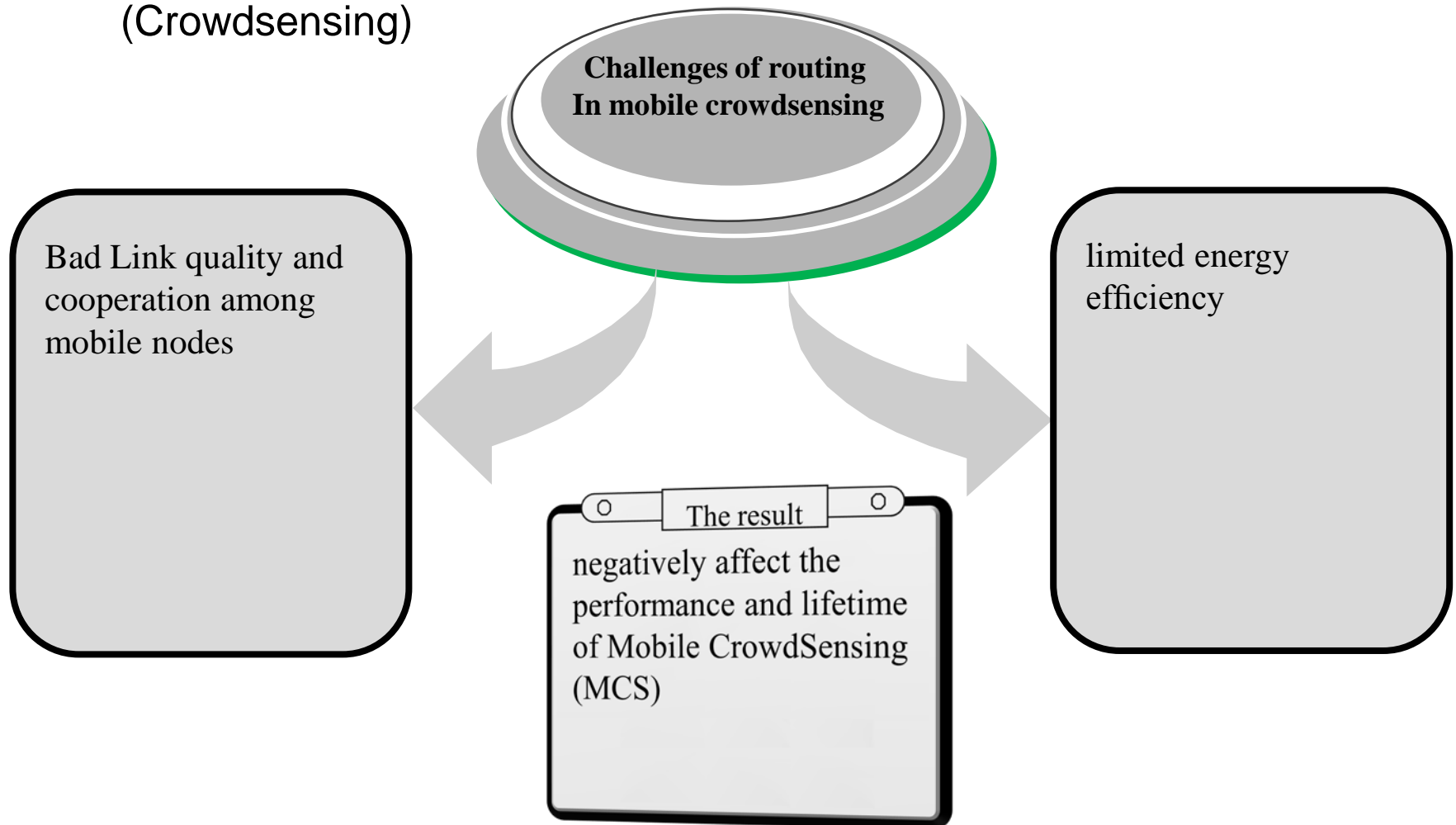
One of the factors, which negatively affects the lifetime of MCS, is inefficient packet routing. Optimal data forwarding can be achieved by favouring not only energy consumption but also link quality, shortest path toward the sink node, and social trust deduced from social networks. This is because only considering a path with highest average residual energy might run out battery of sensor nodes [5], [6]. Thus, in next hop selection it is important to consider a relay node with highest

Outline

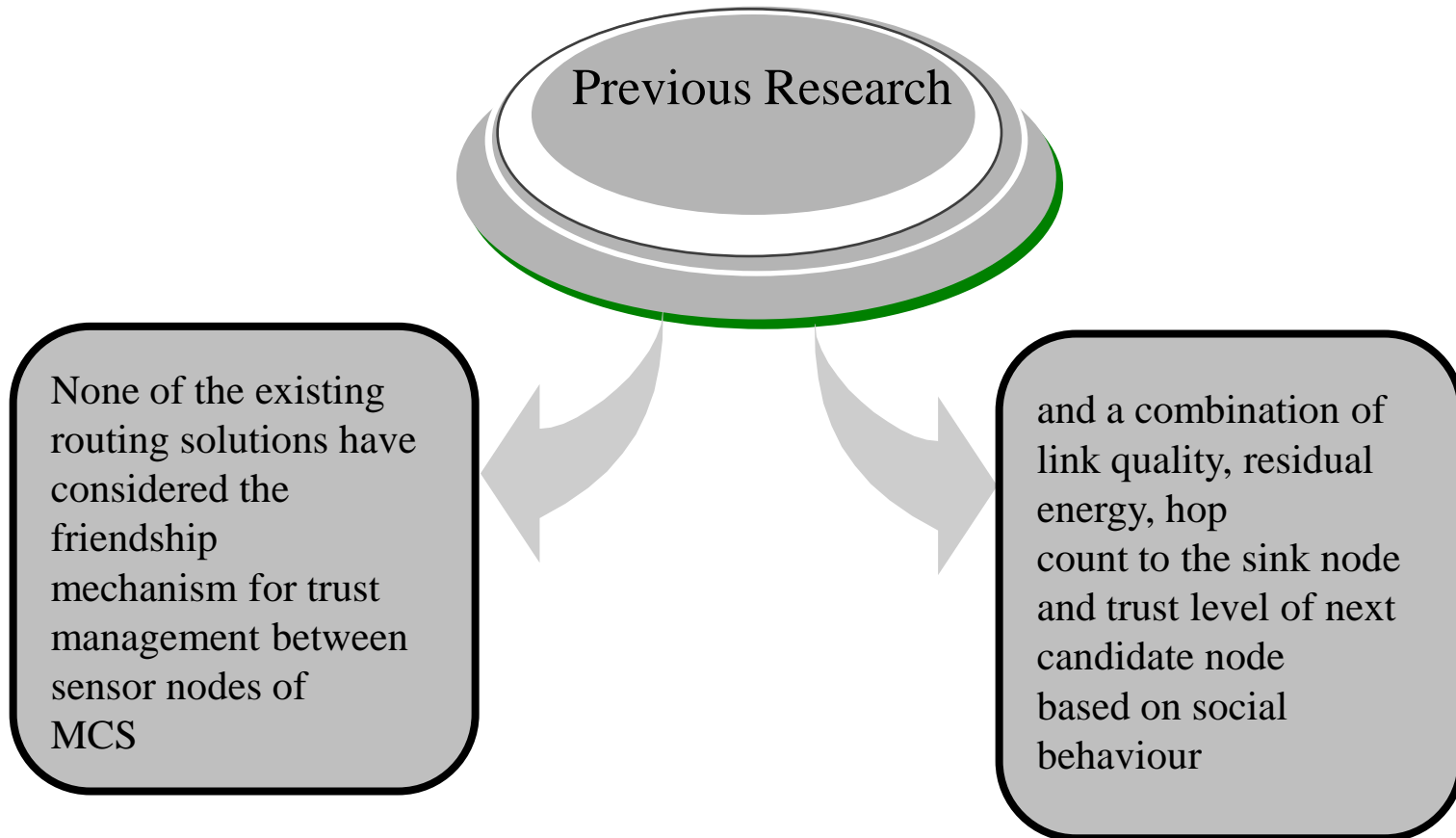
- Overview
- Problem Background
- Research Objectives
- Proposed FR Approach
- Simulation Results
- Conclusion and Future Directions

Overview

- Collecting urban data
 - Noise, temperature, air quality, ...
 - Human as a sensor (Crowdsensing)



Problem Background



Research Objectives

- Only considering single metric for packet forwarding might lead to sub-optimal decision. To tackle the issue, the proposed FR scheme trades-off between energy efficiency, link quality, and privacy of packet forwarding.
- Considering trust management, in contrast to most routing protocols, the FR scheme utilizes friendship mechanism to favour close friends in packet forwarding.
- We implemented and evaluated the proposed FR protocol in OMNeT++. The FR solution outperforms energy- and- shortest path aware routing in terms of network lifetime and packet delivery ratio.

THE PROPOSED FUZZY-BASED ROUTING PROTOCOL

- Fuzzy inference capability is used to control the routing process toward destination.

Algorithm 1 Neighbour node selection mechanism in MCS

Initialize *friendship weight* to sensor nodes

while source *node_i* Active **do**

if source has packet **then**

for all nodes $i \in N_{neighbors}$ **do**

 find node quality for neighbour sensors

 find link quality based to sensor nodes

 call the procedure of fuzzy inference system

 get the value of node cost for all neighbours

end for

 Output maximum value of node cost

 forward packet to selected node N_{th}

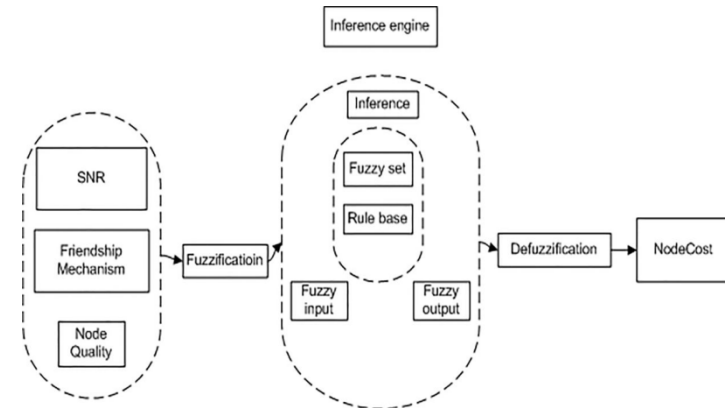
while acknowledge packet NOT recieved **do**

 calculate utilized energy **AND** indicate residual energy of node N_{th}

end while

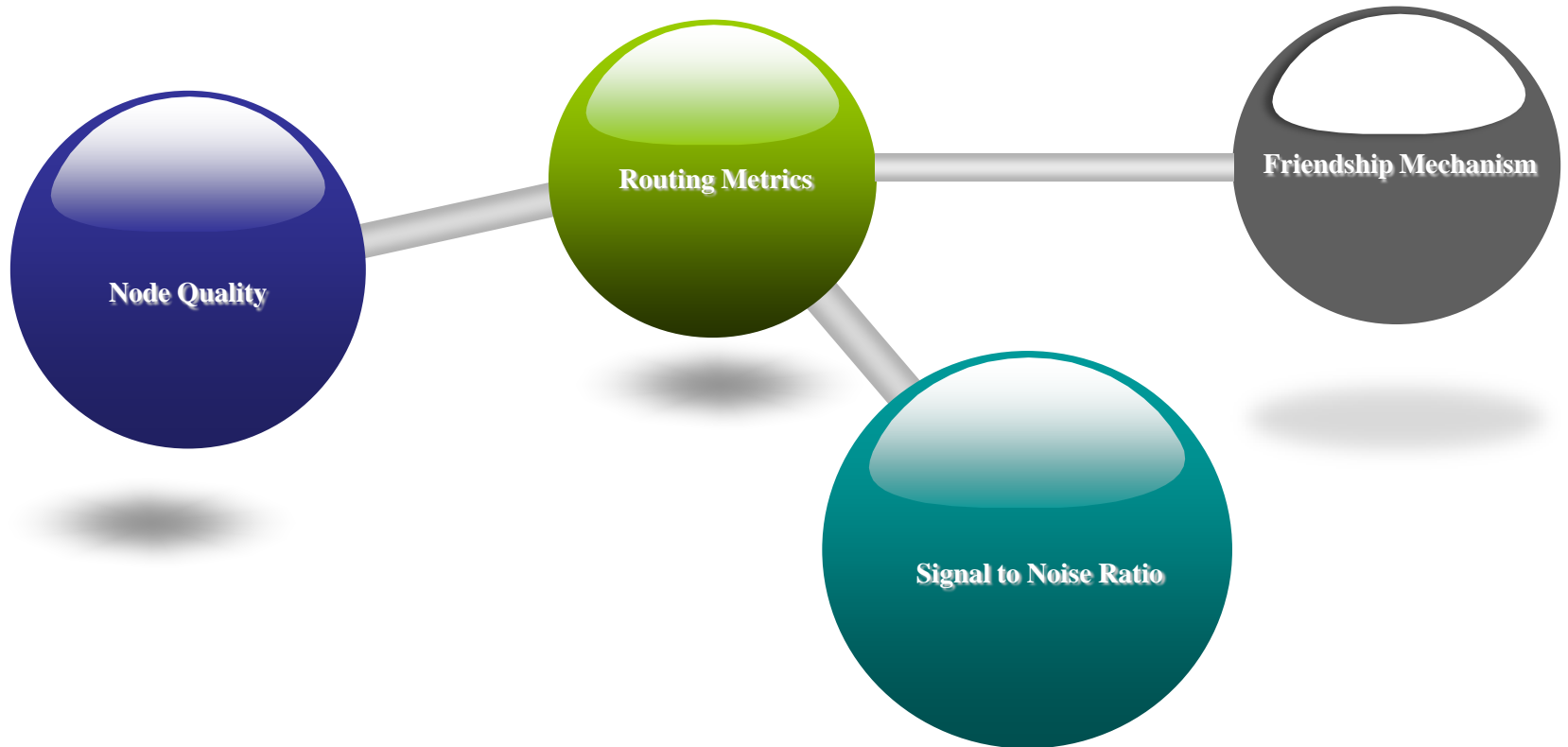
end if

end while



Analytical Model

- **Modeling routing metrics is significant.**



Analytical Model

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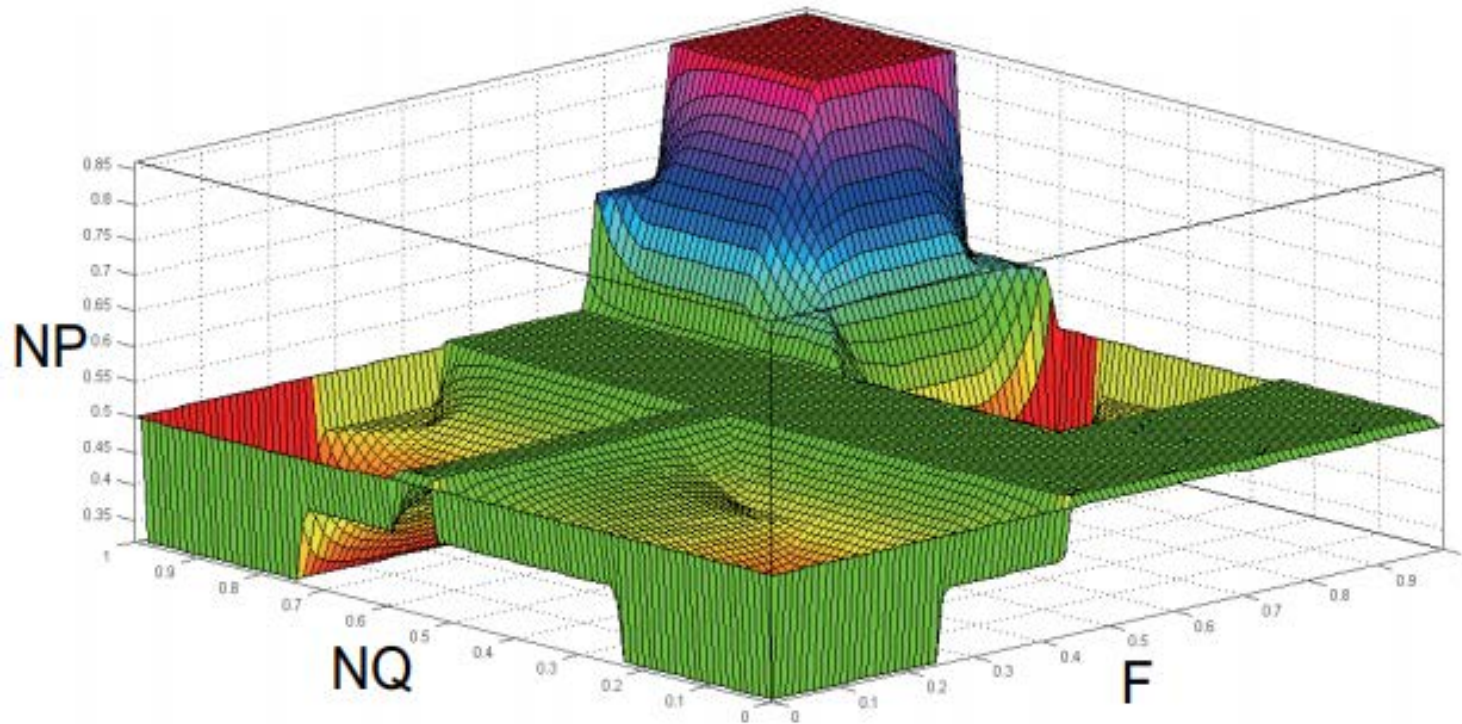


Fig. 3: Correlation between input and output.

Analytical Model

□ Node Quality:

- In order to rank neighbour nodes, source node has minimum and maximum range for each forwarding metric as $[\lambda_k^{\min}, \lambda_k^{\max}]$. Then, a general multi-metric function is defined in equation 1:

$$F(\lambda_1, \lambda_2, \dots, \lambda_k) = x \times \lambda_1^{\alpha_1} \times \lambda_2^{\alpha_2} \times \lambda_3^{\alpha_3} \dots \lambda_k^{\alpha_k} + y_{\max}, \quad (1)$$

- For node quality calculation, the proposed algorithm uses α_1 and α_2 as weighting factors for number of hops (h) and residual energy (e) respectively:

$$F(h, e_i) = x \times h^{\alpha_1} \times e^{\alpha_2} + y_{\max}, \quad (2)$$

where

$$x = \frac{-y_{\max}}{h_{\max}^{\alpha_1} \times e_{\max}^{\alpha_2}}. \quad (3)$$

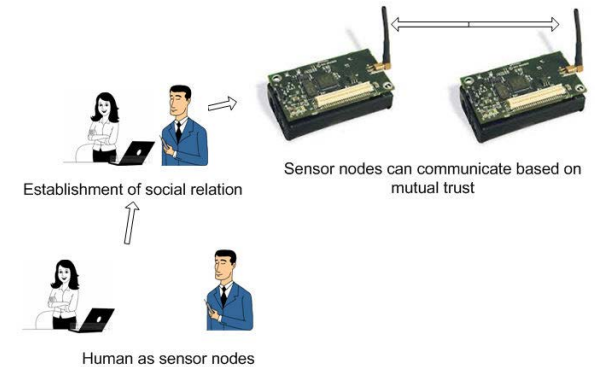
Analytical Model

□ Friendship Mechanism:

Friends of friend relationship can be build based on the good reputation of other mobile crowd sensors. In the simulation, random numbers represents f and ff and assigned to the nodes in wireless sensor scenario. Through beacon exchange mechanism a source node measures f and ff of candidate nodes. For trust cost calculation, the proposed FR uses f and ff as given in equation 4:

$$F(f, ff) = x \times f^{\alpha_3} \times ff^{\alpha_4} + y_{\max}, \quad (4)$$

$$x = \frac{-y_{\max}}{f_{\max}^{\alpha_3} \times ff_{\max}^{\alpha_4}}. \quad (5)$$



□ Signal to Noise Ratio

As reference to the simulation, faded SNR is varied with the error rate for faded wireless channel. More precisely, by increasing the channel SNR, error rate is decreasing and link quality is getting improved [15]. This is exactly happen when SNR=45 dB and error rate is 10^{-5}

Fuzzy Inference System

A. Rule Base

- The fuzzy rules are designed based on requirement of the sensor network. For example, favouring link quality, low energy consumption and high reliable link are significant in order to select next packet forwarder.

Rule	IF			THEN
	Node Quality	SNR	Friendship	Node Priority
1	Low	Low	NotClose	Low
2	Low	Medium	NotClose	Low
..
26	Medium	Medium	VeryClose	Medium
27	Medium	High	VeryClose	High

- a node is selected as next packet forwarder based on metrics of Node Quality (NQ), SNR and Friendship mechanism (F). The output parameter is the Node Priority (NP)

Performance Evaluation

□ In order to validate the performance of FR protocol, fuzzy based Energy and Shortest path aware Routing protocol ESR [13] is used as a benchmark algorithm. The routing protocols are compared based on the following evaluation metrics:

- 1) Reception ratio: determines the number of packets transmitted to the packets successfully received.
- 2) Energy loss: measures energy loss per unit time
- 3) Number of alive nodes: measures the time when the first node running out of energy.
- 4) Total network residual energy: measures the total residual energy of all nodes.

Performance Evaluation

TABLE II: Simulation parameters.

Parameters	Value
Simulation time	1000 s
Simulation area	1000 m \times 1000 m
Mobility model	Constant Speed Mobility
Traffic density	40-60 nodes
Node velocity	0,5,10,15 m/s
Transmission range	100 m
Battery.nominal	10 mAh
Battery.capacity	5 mAh
Battery.voltage	3.3 V
MAC protocol	IEEE 802.15.4
Data packet size	24 bytes
Weighting factors ($\alpha_1, \alpha_2, \alpha_3, \alpha_4$)	(0.1, 0.1, 0.1, 0.01)

Simulation Results

□ *Number of Alive Nodes:*

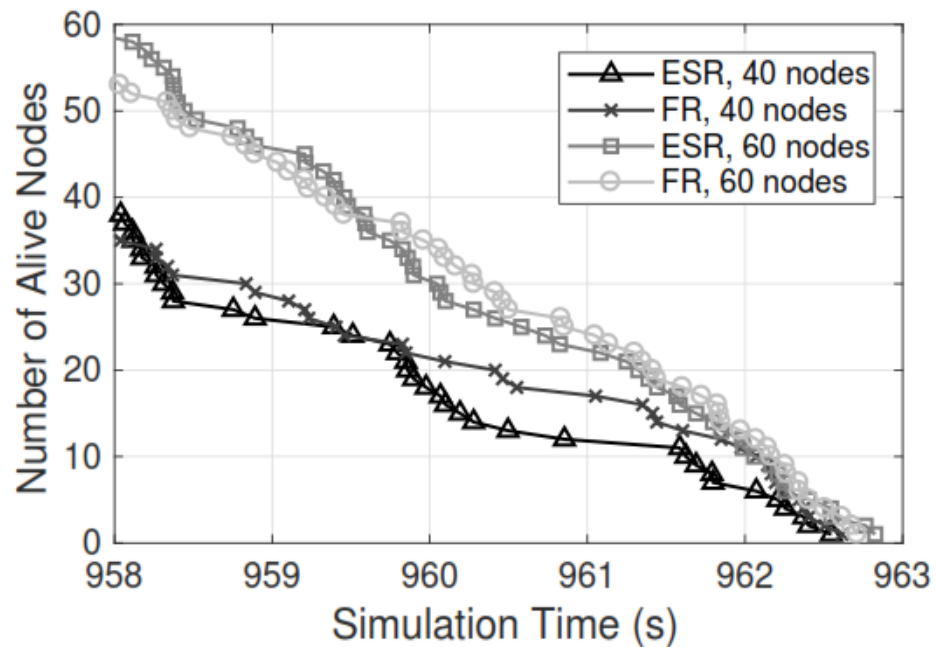


Fig. 4: Number of alive nodes with simulation time.

Simulation Results

□ *Residual Energy:*

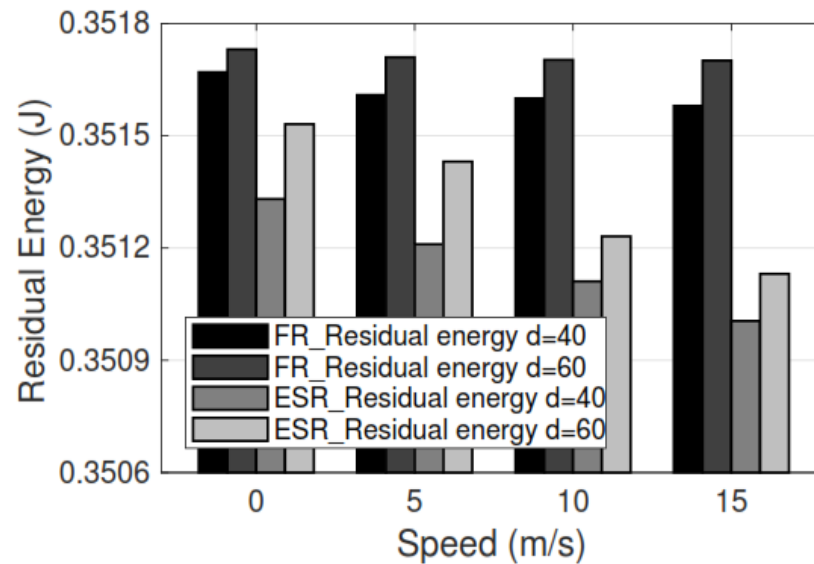


Fig. 5: Residual energy with variation of node speed.

Simulation Results

□ *Total Network Residual Energy:*

<i>Simul. time(s)</i>	<i>FR 10 m/s 40 nodes</i>	<i>FR 15 m/s 60 nodes</i>
0	2340023.5	3547249.25
5	2327617	3528644.75
10	2315211	3510033.5
15	2302805.75	3491427.25
20	2290400.25	3472816
25	2277994.5	3454210.75
30	2265589.75	3435600.25
35	2253183.75	3416989.5
40	2240779.75	3398384.75
45	2228376	3379773.75
50	2215972.5	3361169.75
55	2203568.75	3342563.75
60	2191166	3323958
65	2178762.25	3305353
70	2166358.75	3286748.75
75	2153955.5	3268141.5
80	2141551.5	3249536.75
85	2129148.75	3230931.75
90	2116745.5	3212326.75
95	2104341.5	3193721.5
100	2091938.5	3175117
105	2079534.625	3156510.5
110	2067130.625	3137905.5
115	2054727.875	3119300
120	2042324.125	3100694.25
125	2029920.125	3082089.25

Simulation Results

□ *Battery Life :*

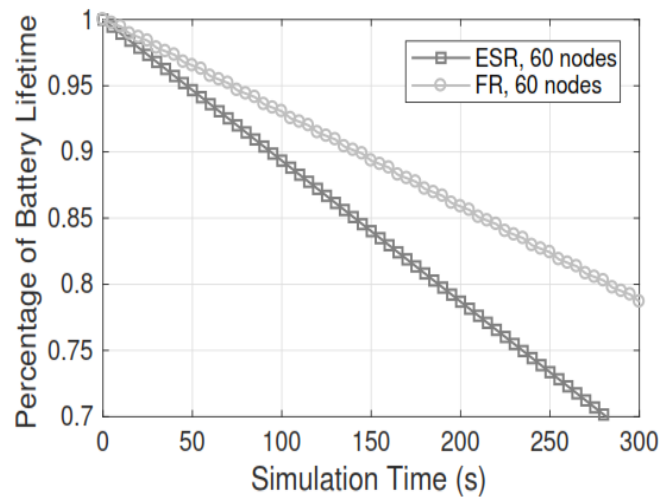


Fig. 6: Percentage of battery lifetime.

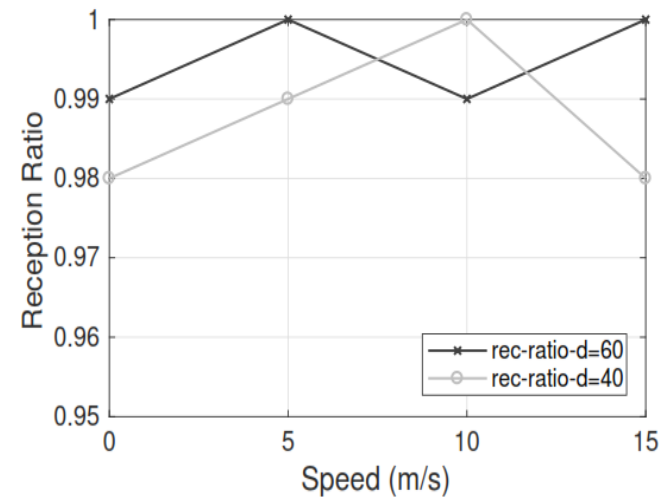


Fig. 7: Effect of sensor node speed on the total network residual energy.

Simulation Results

□ *Battery Life :*

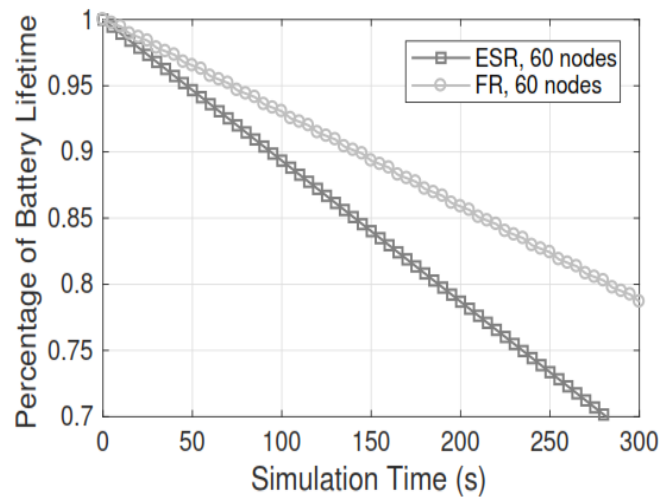


Fig. 6: Percentage of battery lifetime.

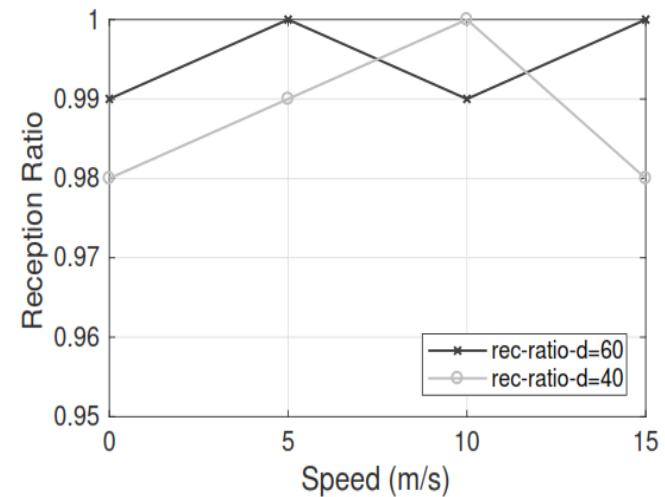


Fig. 7: Effect of sensor node speed on the total network residual energy.

Conclusion

- ❑ we presented Fuzzy logic based Routing (FR) to wisely forward data from a source to sink node in MCS.
- ❑ FR protocol utilized friendship mechanism, link and node quality metrics to decide next relay node election.
- ❑ Simulations have been carried out and the results shown that FR outperformed energy and shortest path-aware routing in terms of network lifetime, remaining residual energy and forwarding performance.

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