A Remedial Pre-Quarantine Perspective to Worm Propagation Defense Modeling for Wireless Sensor Networks Using a Combination of Differential Equation and Agent-Based Approaches

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ABSTRACT
Investigations have shown that recent models that characterize spread of malicious codes have failed to account for certain characteristics of a real network which can be exploited to aid faster containment of worms. Specifically, we identified the absence of uniform random distribution (i.e. sensor deployment) and disease status check for incoming nodes into the sensor field (i.e. access control). Advancing these models (using the epidemic theory) to include these features for Wireless Sensor Networks (WSNs) underpins our research. We would use the differential equation and agent-based modeling paradigms to represent time-related and spatial dynamics of worm propagation.

CCS Concepts
• Hardware → Communication hardware, interfaces and storage →Wireless integrated network sensors

Keywords
Wireless sensors, Agent-based modeling, differential equation

1. PROBLEM STATEMENT
The extensive use of WSN and its deployment in harsh unreachable terrains make them easy prey for worm attack. Recent models that didn't account for sensor deployment and control which would constitute our research are SEIRS-V[3]; SEIQR[2] and SEIQRS-V[5]. There is no information on the effects of distribution density and communication range (*r*) and sensor deployment area types on Exposed, Quarantined and Vaccinated nodes. Figure 1 shows the range between sensor nodes.

Although [9] built a maintenance mechanism that performs "infection check"; their work modeled a closed population with no node inclusion or node loss (due to infection/hardware failure). The model also ignored the possibility that immigrant nodes might carry a worm. So are these models; SEIR [4] and SEIRS-V [3] etc.

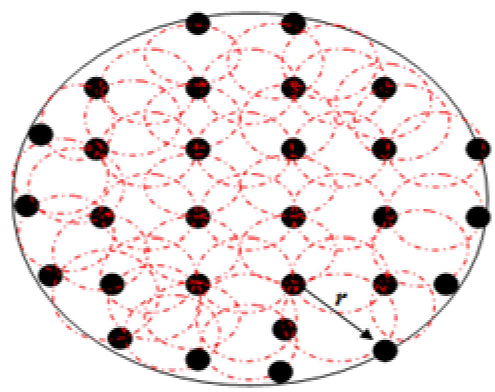

Figure 1: Topological Structure of a WSN

2. RELEVANCY
Our analyses on uniform random distribution (URD) would inform organizations using WSN on the best way to deploy sensors in order to inhibit faster worm propagation. It would also elicit information on the particular deployment area that encourages the spread of worms thereby impacting sensor deployment decisions.

Since network access control (NAC) hasn't been settled for WSN, we embark on our study in order to add to what is already in existence using the epidemic theory. It is our hope that adding NAC (through our pre-quarantine mechanism) we can harden the sensor network, prevent worm attacks, and eliminate unauthorized access by illegitimate nodes.

3. BACKGROUND AND RELATED WORK
The journey of developing analytical models for disease propagation started with SIR [1]. Since then other models has been developed to address issues. These models include SIS, SEIR, SEIRS-V, SEIQR, SEIQRS-V etc. Here, technological networks are treated like a dynamical system. Its stages include; model formulation; finding its equilibrium points, deriving the Reproduction number, showing proof of stability; performing simulation experiments.

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4. RESEARCH METHODOLOGY

We would apply the differential equation and agent-based modeling approaches. The equation approach would characterize the temporal parameters while the agent oriented programming would represent spatial parameters existent in a real world sensor network. Our key innovation is the introduction of a pre-quarantine mechanism to check disease status for incoming nodes and to provide remedial measures (NAC).

5. PRELIMINARY RESULTS

Firstly, we produced a survey report on the usage (and weaknesses) of known epidemic models of computer and wireless networks [6]. Secondly, we highlighted the impact of URD for a circular strip sensor field [7]. To improve recovery rate of infectious nodes, we applied the pre-quarantine mechanisms in SEIR and SEIRS-V model modifying them to QSEIR and QSEIR-V [8].

6. EVALUATION PLAN

We would compare the simulation experiments of both modeling approaches. Thereafter, we would compare the results of our modified models with results of the original models. Using the SEIRS-V model we would also perform comparative analysis with expressions for sensor URD i.e. $(\sigma\pi {r_0}^2)$ for a circular area [9] and $(\pi r^2/L^2)$ for a square area.

7. EXPECTED CONTRIBUTION

Our work would enhance better understanding of the factors that aid worm propagation. It would present a formalized mathematical treatment for NAC in WSN literature. It would derive more accurate Reproduction numbers for worm extinction in models mentioned above. And show how/why our models exhibit non-vanishing recovery at the Disease Free Equilibrium contrary to several works in literature. The study would provide theoretical foundation for controlling/forecasting of worms in the presence of NAC.

8. REFLECTIONS

Research can arise by finding and applying expressions for other categories of sensor deployment aside the “Fixed, no control” type described with URD. URD can be applied to a multi-group model. Pursuit of other mathematical objectives such as performing global stability analyses can ensue. Providing survey reports for usage of epidemic models in P2P networks would constitute our future work.

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