Thesis Defense

Computer Science Master's Program

"A Security Framework for Pacemaker Lead Failure: Anomaly Detection System and Failsafe Policy Considerations"

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Abstract:

Embedded system security in implantable medical devices (IMDs) remains an underexplored challenge due to the unique constraints of these systems. Specifically, pacemakers are optimized for ultra-low power consumption to maximize device lifespan, are highly resource constrained, and demand reliable and correct operation to prevent severe health consequences. Therefore, pacemaker lead integrity is a critical issue, as malfunction or compromise can result in device failure jeopardizing patient safety.

The security framework presented in this thesis integrates several works to proactively detect and address lead failure issues in pacemaker systems. The framework is then applied with a proof-of-concept anomaly detection system (ADS) for lead compromise, system compromise, and malicious or unauthorized communications. The security module makes appropriate system adjustments before yielding to failsafe mode. System failsafe operation is guided by proposed failsafe policy.

The framework can feasibly be implemented on current pacemaker systems but requires systems to have 309 KB of available flash memory and marginally increases system wake time and energy consumption. The proof-of concept estimates a 45% increase (512 KB) in flash memory but incurs less than a 4.2% (0.21 ms) sensing latency overhead with sequential prediction of three models with a compatible ML accelerator and $3.8 * 10^{-5}$% (5 µJ to 44mJ) annual energy consumption overhead depending on usage frequency. The performance of the overall ADS is dependent on model selection, but the suggested nonoptimized autoencoder and multi-layer perceptron (MLP) models yield an approximate area under the curve (AUC) of 0.86 and an F1 score of 99.960, respectively. Altogether, the framework, proof-of-concept, and failsafe policies provide a foundation for future implementation and testing of security features for pacemakers.

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Time: 3:00 PM – 5:00 PM
Zoom Link: https://calpoly.zoom.us/j/81624004100
Committee: Dr. Stephen Beard, Dr. Bruce DeBruhl, and Dr. John Oliver