WiP Abstract: A Physiology-Aware Communication Architecture for Distributed Emergency Medical CPS

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ABSTRACT

For emergency medical cyber-physical systems, enhancing the safety and effectiveness of patient care, especially in rural areas, is essential. While the doctor to patient ratio in the United States is 30 to 10,000 in large metropolitan areas, it is only 5 to 10,000 in most rural areas; and the highest death rates are often found in the most rural counties [3]. Use of telecommunication technologies can enhance effectiveness and safety of emergency ambulance transport of patients from rural areas to a regional center hospital. It enables remote monitoring of patients by the physicians at the center hospital and provides vital assistance to the emergency medical technicians (EMT) to associate best treatments. However, the communication along the roads in rural areas can range from 4G to 2G to low speed satellite links, with some parts suffering from communication breakage. This unreliable and limited communication bandwidth together with the produced mass of clinical data and the many information exchanges pose a major challenge in real-time supervision of patients.

During this research, we are developing a novel adaptive physiology-aware communication architecture which is aware of the patient condition, the underlying network bandwidth, and the criticality of clinical data in the context of the specific disease to achieve an enhanced remote monitoring. Further, it features *reliability*, *safety*, and *fault tolerance* for cases such as network interruption.

CCS CONCEPTS

•Networks →Network architectures;

KEYWORDS

Physiology-aware communication, medical CPS, distributed models

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METHODOLOGY OVERVIEW

The main goal of our research is to propose an adaptive model-driven communication architecture for dynamic physiological systems that are distributed across a rural hospital, a tertiary center hospital, and an ambulance. The objective of our proposed physiology-aware communication architecture is to promote the smoothness and effectiveness of emergency patient care under such distributed settings. Using the concept of distributed model-driven physiological automata, we seek to exploit the semantics relation of clinical data communication, criticality of clinical data, and an

ambulance's undertaken route in a disease-specific manner. In summary, the major challenges include, but are not limited to:

- Dynamic distribution of expertise, facilities, and physiological best-practice models among a rural hospital, an ambulance, and a center hospital
- Patient monitoring in ambulances under limited and variable bandwidth given the rural environment, and
- Communication breakage in parts of major routes, especially along rural routes.

To address the challenges above, we seek the following contributions throughout our research.

- (1) Proposing the notion of distributed physiological best-practice systems and to model them as communicating medical executable automata. Within this context, we propose model-driven message-exchange communication mechanisms to enable executable medical models to exchange messages with each other so that their states get synchronized in a safe manner. We design a physiology-aware communication protocol that meets the *reliability* and *safety* requirements of emergency care with support of message prioritization. We partially implemented and evaluated our physiology-aware communication architecture over multiple executable medical models conducted in collaboration with Carle Foundation Hospital [1, 3, 4].
- (2) Design of a bandwidth-compliant criticality-aware system for transmission of clinical data adaptive to varying bandwidths and patient's varying physiological states during ambulance transport in rural areas. Our adaptation techniques aim to transmit more critical clinical data with higher fidelity in response to changes in both bandwidth and patient condition. As a part of our contributions, we developed a bandwidth profiler in collaboration with Carle's ambulance service center, and used that to collect various geo-communication traces to support our experiments [2].
- (3) Design of a disease-aware ambulance route scheduler integrated into our physiological communication architecture to assist ambulances pick the best route when continuous network coverage is needed for real-time remote monitoring of patients. Our novel physiological scheduler seeks trade-offs in travel time and availability of continuous network coverage during ambulance patient transport which aims to minimize a cost function through approximation of an NP-hard problem.

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