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Physiologically-Aware Communication Architecture for Transmission of Biomedical Signals in BASNs for Emerging IoT Applications

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Abstract

This research work proposes a novel physiologically-aware communication architecture for the transmission of biomedical signals in BASNs (Body Area Sensor Networks) and wearables for emerging IoT applications. The architecture to fulfill the following objectives:

• Reduce volume of biomedical data in IoT networks and Internet infrastructure.
• Minimize the required computational load of biomedical data on the cloud side.
• Extend the lifetime of the mobile wearable/BASN through improved energy savings.

The above goals are achieved with proposed architecture (shown center/right):

• Feature-extraction and pre-diagnosis on biomedical signal via D-stage (2) to assign a ‘score’ representing patient health state called Diagnostic Condition Level (DCL).
• Signal is manipulated in the wavelet domain by the Q-stage (3) for eventual compression while working to preserve the features of clinical significance.
• Q-stage impact is evaluated via feature-based Diagnostic Distortion Measure (DDM) (1) to establish hard limits that would result in loss of clinical features by Q-stage.
• The resulting bitstream is sent to the transmission pipeline for further processing before eventual transmission (4).
• All pipeline parameters in (4) can change in real-time as the patient health state (DCL) changes, balancing signal quality, urgency, and energy efficiency.

Experimental Work

Experimental work was simulated and conducted in MATLAB:
• Experimental work focused on ECG-class signals as “proof-of-concept” behind research work.
• Five, 30-minute ECG records were used from PhysioNet’s ECG database.
• Records: 100, 106, 107, 108 are of patients with various degree of Arrhythmia.
• Record 10625 is Normal Sinus for ground truth.
• Simulation work focused on characterizing energy by transmission pipeline in (4) given wireless transmission costs are much higher than computation costs.

Results

In no particular order:
• Plot (2) shows D-stage performance of ECG (top).
• The middle plot in (2) shows feature-extraction of patient health state in the form of heart rate "jitter" (middle).
• Bottom plot in (2) shows the DCL score, changing as a function of patient health state.
• Plot (3) shows performance of Q-stage comparing impact on signal quality in wavelet domain using four special “truncation modes”
• Some truncation modes are better at preserving signal quality with respectable gains in compression ratio.

(Dcont’d)
• Plot (1) shows performance of feature-based diagnostic distortion measure (DDM).
• DDM allows us to actually “observe” when features of clinical significance actually disappear (top) by Q-stage effects.
• It compares DDM against sample-based distortion measures (e.g., PRD and WWPRD).
• Plots in (4) show energy performance of transmission pipeline.
• Left plot in (4) shows how energy changes for each packet transmitted as function of patient health state in a variety of modes: RAW mode, and our methods (homogeneous and heterogeneous data).

Conclusion

This architecture is generalizable to class of biomedical signals. It prevents large volume of biomedical data to be generated; uses patient state to control almost any system parameter; achieves significant energy savings, helping to extend the lifetime of the device for medical-IoT applications.