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[Faculty of Electrical Engineering and Computer Science]

Bachelor's Thesis

BLUETOOTH LOW ENERGY: A SMART APPROACH TO WIRELESS ECG MONITORING

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DEPARTMENT [ELECTRICAL ENGINEERING]

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Περίληψη:

Το ακόλουθο έγγραφο βασίζεται σε έρευνα σχετικά με το πρωτόκολλο επικοινωνίας του Bluetooth Low Energy (BLE), για τη χρήση του σε ιατρικές εφαρμογές. Συγκεκριμένα, για τη χρήση σε πραγματική παρακολούθηση ασθενών και καταγραφή δεδομένων, μέσω της δημιουργίας ενός προσαρμοσμένου Ηλεκτροκαρδιογράμματος (ΗΚΓ) με χρήση ειδικού υλικού και λογισμικού, συνοδευόμενου από προσαρμοσμένες εφαρμογές για κινητά (app).

Μέσω της έρευνας σε πρωτόκολλα επικοινωνίας (όπως το BLE, το κλασικό Bluetooth (BT), το Wi-Fi και το Zigbee), αποκτήθηκαν σημαντικές πληροφορίες σχετικά με τη μεθοδολογία που ακολουθήθηκε, καθώς και για τα μετρικά που ήταν σημαντικά όχι μόνο για τη σύγκριση των πρωτοκόλλων, αλλά και για να θεωρηθούν αποδοτικά για μια εφαρμογή με ευαίσθητα δεδομένα, τα οποία εάν αλλοιωθούν μπορούν να οδηγήσουν σε σοβαρές συνέπειες.

Για την επίτευξη του τελικού στόχου, δηλαδή της δημιουργίας μιας εφαρμογής παρακολούθησης ΗΚΓ, πραγματοποιήθηκαν αρκετές απαραίτητες δοκιμές. Ξεκινώντας με δοκιμές σύνδεσης και απόδοσης του BLE, ο στόχος ήταν η λήψη μετρικών υπό διαφορετικές συνθήκες και ρυθμίσεις. Αυτό βοήθησε στη συνέχεια στην αξιολόγηση των ιδανικών συνθηκών και της ιδανικής ρύθμισης για την τελική ιατρική εφαρμογή BLE. Με βάση το συνδυασμό αυτών των δοκιμών, καθώς και την έρευνα σε επαγγελματικά ΗΚΓ, δημιουργήθηκε η τελική εφαρμογή για πραγματική παρακολούθηση ΗΚΓ μέσω BLE.

Για κάθε δοκιμή που πραγματοποιήθηκε και για κάθε εφαρμογή που δημιουργήθηκε, χρησιμοποιήθηκε μια διαφορετική διαμόρφωση υλικού/λογισμικού, συνοδευόμενη από υπολογιστικά εργαλεία (π.χ. MATLAB) όταν ήταν απαραίτητο. Επιπλέον, ο σχεδιασμός της ροής εργασιών και του σχεδίου έπαιξε σημαντικό ρόλο στα αποτελέσματα των δοκιμών, τόσο για τα μετρικά όσο και για την επόμενη ροή εργασιών.

Τέλος, η έρευνα που πραγματοποιήθηκε, εκτός από τη διαφώτιση του πρωτοκόλλου επικοινωνίας BLE, βοήθησε επίσης στη δημιουργία της ιδανικής ροής εργασιών, η οποία όχι μόνο προσέφερε τα τελικά συμπεράσματα, αλλά και συμπεράσματα για ολόκληρη τη διαδικασία, συμπεριλαμβανομένων των δοκιμών μετρικών BLE που ήταν απαραίτητες για την τελική υλοποίηση του έργου.

Summary:

The following paper is based on research on the communication protocol of Bluetooth Low Energy (BLE), for its use in medical applications. Specifically, for the use in live patient monitoring and data logging, by creating a custom Electrocardiogram (ECG) using specific hardware and software, accompanied by custom made mobile applications (app).

Through background research on communication protocols (like BLE, Bluetooth Classic (BT) Wi-Fi and Zigbee), which offered insights on how to proceed with the methodology as well as what metrics were important, not only to compare communication protocols, but to also consider them efficient for an application with sensitive data, which if corrupted can even lead to dire consequences.

To achieve the final goal of creating an ECG monitoring app, a few necessary tests took place. Starting off with tests on BLE connectivity and performance, the goal was to retrieve metrics under different conditions and setups. This would later help evaluate the ideal conditions and set-up for the final BLE medical application. Based on the combination of these tests as well as research on medical grade ECGs, the final application for a BLE live ECG monitor was created.

For each test performed and application created, a different hardware/software setup was used accompanied by computational tools (e.g. MATLAB) when necessary. Additionally, the planning of the workflow and design played a major role in the results of the tests both for the metrics and for the following workflow.

Finally, the background research while offering insights into the BLE communication protocol also helped in creating the ideal workflow which not only offered the final conclusions but also offered conclusion for the whole process including the BLE metrics tests which were necessary for the final implementation of the project.

Abstract:

With the rapid advancements of technological development especially in data science and telecommunications, we take the comfort of being able to communicate nearly anywhere for granted. Whether we are in the comfort of our home or in a public space using our Wi-Fi, data roaming or using our providers network, we could never imagine how we would be able to communicate without these.

Taking the above into consideration, one would have to think how this could affect vital parts of our infrastructure such as healthcare facilities or even emergency calls. Where patient monitoring is continuous and data exchange is important how could a network disruption affect monitoring systems?

Although there are already existing technologies which are vastly used for remote patient monitoring, vital signs monitoring (i.e. blood pressure,) and data exchange [3][4], it would be tremendously helpful or even lifesaving, in some situations, if more, smaller portable devices with the capability to work offline or without a network, were developed.

This would solve problems such as transportation and space management, as well as main problems such as network connectivity issues, indoors and outdoors, due to a multitude of factors (e.g. network malfunction, Limited network access, obstacles, power cuts etc.).

Here is where the BLE ECG monitor would be useful. A small device, with a BLE module and an ECG sensor, capable of transmitting live ECG data to a smartphone in order to monitor a patient with a visual graph on the spot. A device like this would be easy to transport, easily handled and with a visual monitor comprehendible to medical staff. In addition, it relies on the BLE communication protocol for relatively short proximity and node to node communication.

This device could prove useful in cases where a fast precautionary diagnosis is needed, such as to be used by paramedics in any scenario, whether it's in a moving ambulance, where both time and space are crucial for both the patients' and paramedics' safety, or whether accessibility is needed to provide health services in a remote area for an emergency!

The use of this device though, would not be limited to emergency use only. Since it could provide an alternative way of point to point (patient to medical staff) data monitoring, where immediate observation is needed. By not relying on mainstream communication protocols (i.e. Wi-Fi), data acquisition and patient monitoring could withdraw itself from any network problems that may arise due to multiple factors as mentioned previously. Additionally, the use of more than one communication protocol for data acquisition in the medical field will isolate communication issues, creating a more private connection between targeted devices.

As a result, this could change the way emergency correspondents and medical infrastructure respond and operate in a variety of situations, especially unexpected ones. Where medical staff would have to respond fast in outdoor settings, or indoors after inconvenient network failures.