Smart emergency heart project: campus network of WearOS smartwatches connected via Firebase database⋆

Dmytro Zubov[1, *,†], Vitaly Levashenko[2,†], Andrey Kupin[3,†] and Nurlan Shaidullaev[1,†]

[1] University of Central Asia, 125/1 Toktogul St., Bishkek, 720001, Kyrgyz Republic
[2] Zilina University, Univerzitná 8215, 010 26 Žilina, Slovakia
[3] Kryvyi Rih National University, 11 Vitaly Matusevich St., Kryvyi Rih, 50027, Ukraine

Abstract

Mountain communities face specific health issues related to high altitude. Existing commercial solutions, such as standard healthcare smartphone applications, usually send data to connected smartphones within a personal area network only. They are not designed for remote data acquisition and analysis. This study presents a new custom software solution developed to monitor heart problems at the Naryn campus of the University of Central Asia, which is situated at an elevation of approximately 2000 m. The IoT system employs a network of Samsung Galaxy 4 40 mm smartwatches to acquire data regarding heart issues of individuals in the context of the Healthcare 5.0 patient-centered approach. This information is then stored in the NoSQL cloud-based Firebase Realtime Database. The project focuses on two crucial vital parameters - tachycardia and cardiac arrest, which are common in high-altitude mountain regions. Campus doctors and other qualified experts can access this data directly through the Firebase console or via custom software, such as a mobile application. The experiment conducted at the Naryn campus demonstrates that smartwatch applications correctly identify abnormal states of vital parameters in a focus group of four people.

Keywords

IoT, Healthcare 5.0, heart emergency, Samsung Galaxy smartwatch, Firebase, high-altitude region

1. Introduction

Heart emergency SOS systems [1, 2] play a crucial role in requesting urgent assistance for individuals with cardiovascular diseases [3], which are common in high-altitude mountain regions [2, 3]. Smart wearable devices, such as smartwatches [4, 5] and Adafruit QT Py ESP32-S2 boards with sensors [1], are essential for acquiring supervisory data used for analyzing and preventing emergencies. Existing commercial products, including Samsung Galaxy Watch [6], Apple Watch [4], Pixel Watch [5], and Raspberry Pi / Arduino-based boards [7, 8], operate autonomously and often connect wearable devices within personal area networks to other hardware like smartphones.

Analysis of previous studies, as presented in references [4-6], indicates that the parallel supervisory data acquisition with project backend software (e.g., the NoSQL cloud-based Firebase Realtime Database [9] connects several applications via backend cloud computing services) is a custom product. This approach is particularly suited for organizations situated on one site with accommodation, different facilities, and leisure activities, such as a university campus. In this study, the Naryn campus of the University of Central Asia served as a testbed for developing a prototype of a heart emergency SOS system. This system employs a network of Samsung Galaxy smartwatches connected via the Firebase Realtime Database.

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[1*] Corresponding author.
† These authors contributed equally.
dzubov@ieee.org (D. Zubov); vitaly.levashenko@fri.uniza.sk (V. Levashenko); kupin@knu.edu.ua (A. Kupin); nurlan.shaidullaev@ucentralasia.org (N. Shaidullaev)
0000-0002-5601-7827 (D. Zubov); 0000-0003-1932-3603 (V. Levashenko); 0000-0001-7569-1721 (A. Kupin); 0009-0003-5165-897X (N. Shaidullaev)

In this project, Samsung Galaxy 4 smartwatches running Google's Wear operating system (OS) 4, based on Google Android OS 13 "Tiramisu," were used to monitor two crucial vital parameters – tachycardia and cardiac arrest. The testbed was the Naryn campus of the University of Central Asia, situated at an elevation of approximately 2000 m in the Kyrgyz Republic. The smartwatch application developed for this project synchronizes data in real-time and stores it as a node with an associated key in the Firebase Realtime Database. This data is then analyzed by campus doctors and other qualified experts.

This paper is organized as follows: Section 2 analyses previous studies in the context of soft-/hardware wearable solutions for heart monitoring. Section 3 discusses two main phases of the project development lifecycle: the smartwatch application with analysis of the heart rate (risk of cardiac arrest or tachycardia); the smartwatch application with analysis of the heart rate and access to the Firebase Realtime Database. Section 4 describes a successful experiment conducted on the Naryn campus of the University of Central Asia, situated at an elevation of about 2000 m. Results and discussion are presented in Section 5. Conclusions are summarized in Section 6.

2. Related works

Up-to-date trends in smart city healthcare systems are described by several stages called Healthcare 1.0, Healthcare 2.0, Healthcare 3.0, Healthcare 4.0, and Healthcare 5.0 [10, 11]. Between 2019 and 2023, around 175 research papers related to smart healthcare systems were indexed in the SCOPUS databases [12]. An analysis of previous studies, such as those presented in [12, 13], shows that the Internet of Things (IoT) is at the forefront of smart healthcare systems. In this study, smartphone and IoT smartwatch applications with the Firebase Realtime database implement the following features of the Healthcare 5.0 platform: a patient-centered approach; and personalized and connected experience for patients and medical doctors. The primary benefits of the developed healthcare subsystem include personalized high-quality care, disease prevention, cost reduction, and remote access to healthcare data.

An analysis of existing wearable hardware shows a limited range of available items, primarily consisting of smartwatches and open-source microcontrollers. Up-to-date smartwatches, such as the Samsung Galaxy 4 and the Apple Watch Hermès, have built-in subsystems for measuring heart rates. This represents a significant advantage over wearable solutions based on Arduino Nano/Uno/Mega and Raspberry Pi [8, 14] or other open-source microcontroller boards like Adafruit QT Py ESP32-S2 and Arduino LilyPad, which additionally require sensors, batteries, and proper installation to operate effectively. In particular, the custom IoT personal sensor [15] consists of three parts (a data acquisition unit MAX30003WING, a control board Nucleo F401RE, and a wireless Internet communication unit STEVAL-STMODLTE) and needs proper installation. The same multiunit approach is employed in [16] (pulse sensor, Arduino Uno, and HC-05 Bluetooth module) and in [17] (heart rate module MAX30102, IoT microcontroller ESP32, and an OLED screen). In addition, multinational IT companies, such as Google LLC, offer backend cloud computing services, including Firebase Realtime Database, to synchronously connect different applications. As of December 2024, the Samsung Galaxy Watch 4 40 mm was the most affordable smartwatch available, priced at approximately USD 115 in Bishkek, Kyrgyz Republic. In comparison, the Apple Watch SE 2024 costs around USD 260, and the Pixel Watch One is priced at about USD 155.

An analysis of existing wearable software shows a limited range of available host OSs, with the most-known WearOS (used by Samsung Galaxy Watch and Pixel Watch) and watchOS (employed by Apple Watch). The selection of the programming language and the development paradigm for smartwatch application depends on the host OS, the organization's specific requirements, and the background of developers. Custom software is developed for several smartwatches that operate in parallel, as data synchronization is necessary for the project's backend.

Since the tachycardia heart rate is known (>100), machine-learning models, such as those presented in [18, 19], are not employed to classify heart events in this study.

In this study, Samsung Galaxy Watch 4 40 mm is employed to measure the heart rate and send the data to the Firebase Realtime Database (for this purpose, a custom application was developed for smartwatch in Android Studio Ladybug 2024.2.1 Patch 3 using a declarative programming approach with Kotlin and Jetpack Compose). This information can then be accessed by campus doctors and other qualified experts (for this purpose, a custom application was developed for smartphones in the same integrated development environment using an imperative programming approach with Java).

The proposed architecture of the heart emergency SOS project employed on the campus network with Samsung Galaxy 4 smartwatches and Firebase Realtime Database is shown in Figure 1. Users

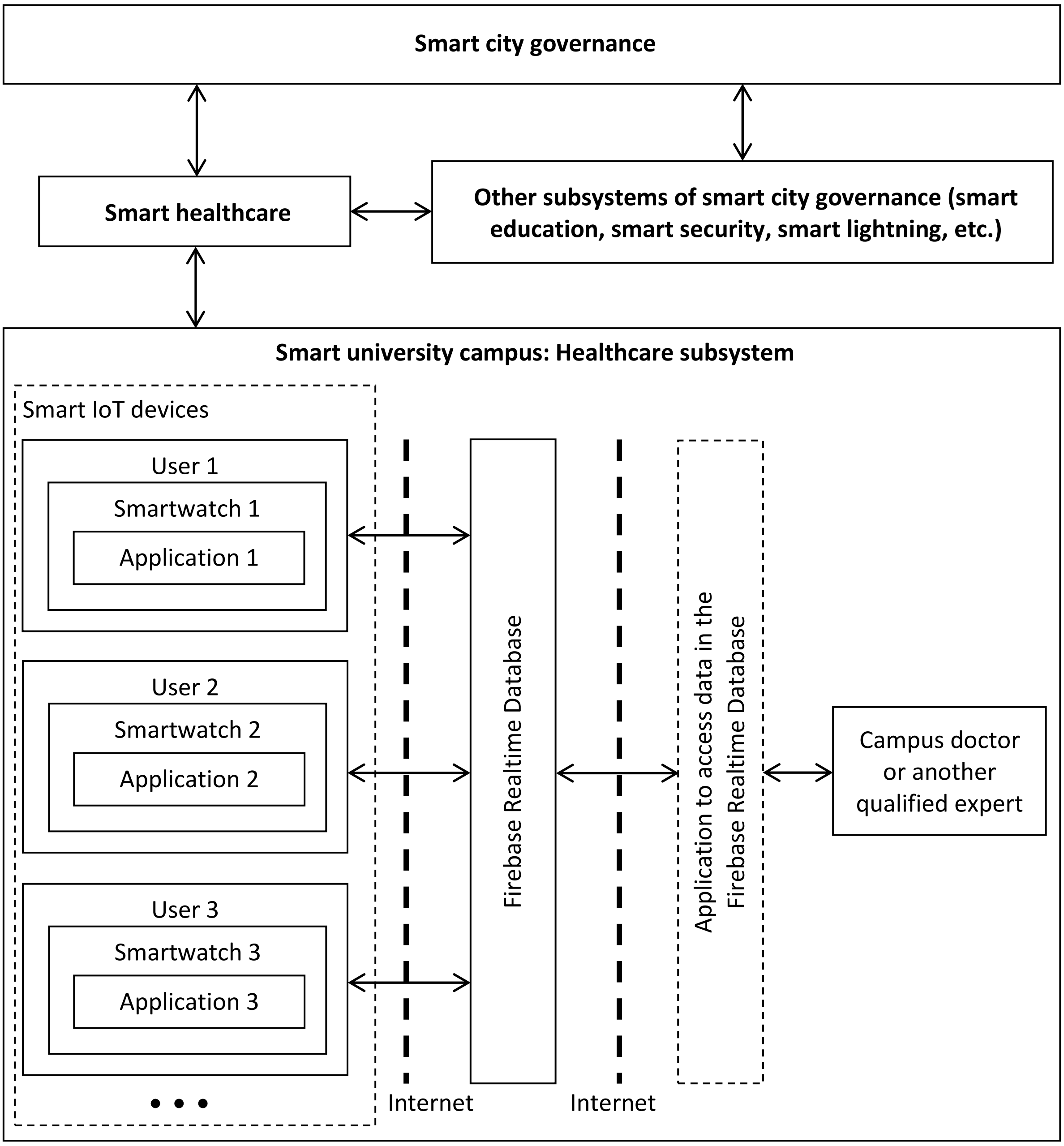


Figure 1: Heart emergency SOS project: Proposed architecture of campus network with Samsung Galaxy 4 smartwatches connected via Firebase Realtime Database.

wear smartwatches to measure their heart rates, which are then transmitted to the cloud-based Firebase Realtime Database. Campus doctors and other qualified experts can access this data through the Firebase console and/or custom software such as a mobile application. This study focuses on the healthcare subsystem of the smart university campus, which is part of the smart healthcare framework within smart city governance. Here, remote communication with IoT devices [14, 20] enhances health monitoring and response capabilities.

3. Methods

The project development lifecycle consists of two main phases:

1. Development of a smartwatch application to analyze the heart rate: tachycardia or risk of cardiac arrest.
2. Acquisition and analysis of the remote healthcare data from smartwatches via the Firebase Realtime Database.

3.1. Development of a smartwatch application to analyze the heart rate

The developed smartwatch application employs the Kotlin programming language and the Jetpack Compose declarative paradigm. The ExerciseSampleCompose code [21] presented on GitHub under Apache License 2.0 was modified in this study. Two substantial updates were implemented in the ExerciseScreen.kt file:

1. Analysis of the low heart rate – the risk of cardiac arrest. The red background will appear for heartbeat information on the exercise screen if the heart rate equals zero.
2. Analysis of the high heart rate – the tachycardia. The red background will appear for heartbeat information on the exercise screen if the heart rate exceeds 100 beats per minute in the last ten measurements.

Figure 2 shows the screenshot of the Android Studio Ladybug 2024.2.1 Patch 3 window with the modified Kotlin code in the function/object-oriented programming method HeartRateRow (red border rectangle 1) in the file ExerciseScreen.kt (red border rectangle 2) and the connected smartwatch Samsung Galaxy 4 (red border rectangle 3).

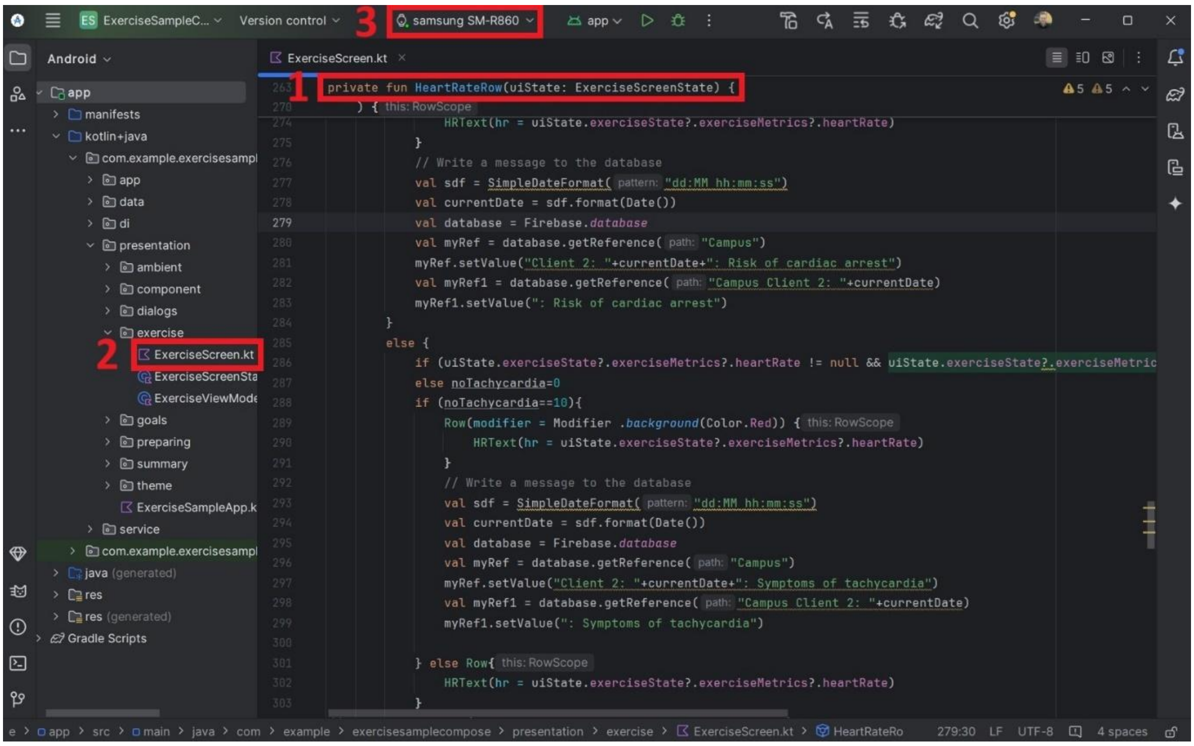
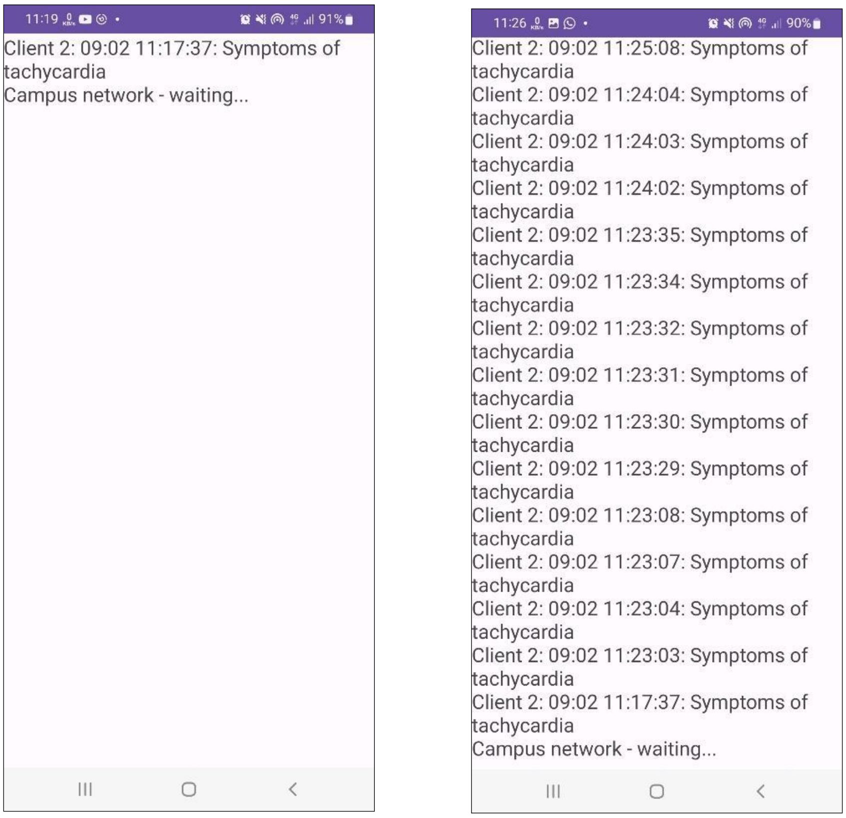


Figure 2: Screenshot of the Android Studio Ladybug 2024.2.1 Patch 3 window with the modified Kotlin code in the function HeartRateRow (red border rectangle 1) in the file ExerciseScreen.kt (red border rectangle 2) and the connected smartwatch Samsung Galaxy 4 (red border rectangle 3).

3.2. Acquisition and analysis of the remote healthcare data from smartwatches via the Firebase realtime database

First, the information about two vital parameters, tachycardia and risk of cardiac arrest, is transmitted from smartwatches to the Firebase Realtime database. Campus doctors and other qualified experts can then access this data directly from the smartphone mobile application (see Figure 3) or from the Firebase console (see Figure 4).



a) b)

Figure 3: Examples of information about vital parameters, tachycardia and risk of cardiac arrest, received on the smartphone mobile application from the Firebase Realtime database: screenshots were taken at the application launch (A) and after the activity has been running for about eight minutes (B).

Figure 3 shows two screenshots of the mobile application on the smartphone Samsung Galaxy M31 SM-M315F/DSN: the first one was taken at the application launch, and the second one shows the activity after it has been running for about eight minutes. A custom smartphone application was developed in Android Studio Ladybug 2024.2.1 Patch 3 using an imperative programming approach with Java. The activity is of the ConstraintLayout type with one scrollable widget TextView that matches the screen size. In the current version, the TextView element includes a maximum of 100 records.

Figure 4 presents an example of the Firebase console with information from the user named "Client 2". Two types of hierarchical database nodes are employed in this project:

1. "Campus": only one line, i.e., only one database node, inside the red rectangle in Figure 4 is used to transmit information from the smartwatch to smartphone(s).
2. "Campus Client number: dd:mm hh:mm:ss: Vital parameter": lines inside the blue rectangle represent the information transmitted from the smartwatch to the Firebase Realtime Database. The information is not filtered since a higher number of records may help to

identify false alarms. For instance, one line with the warning about the risk of cardiac arrest can occur when the user wears a smartwatch, and the application starts collecting data.

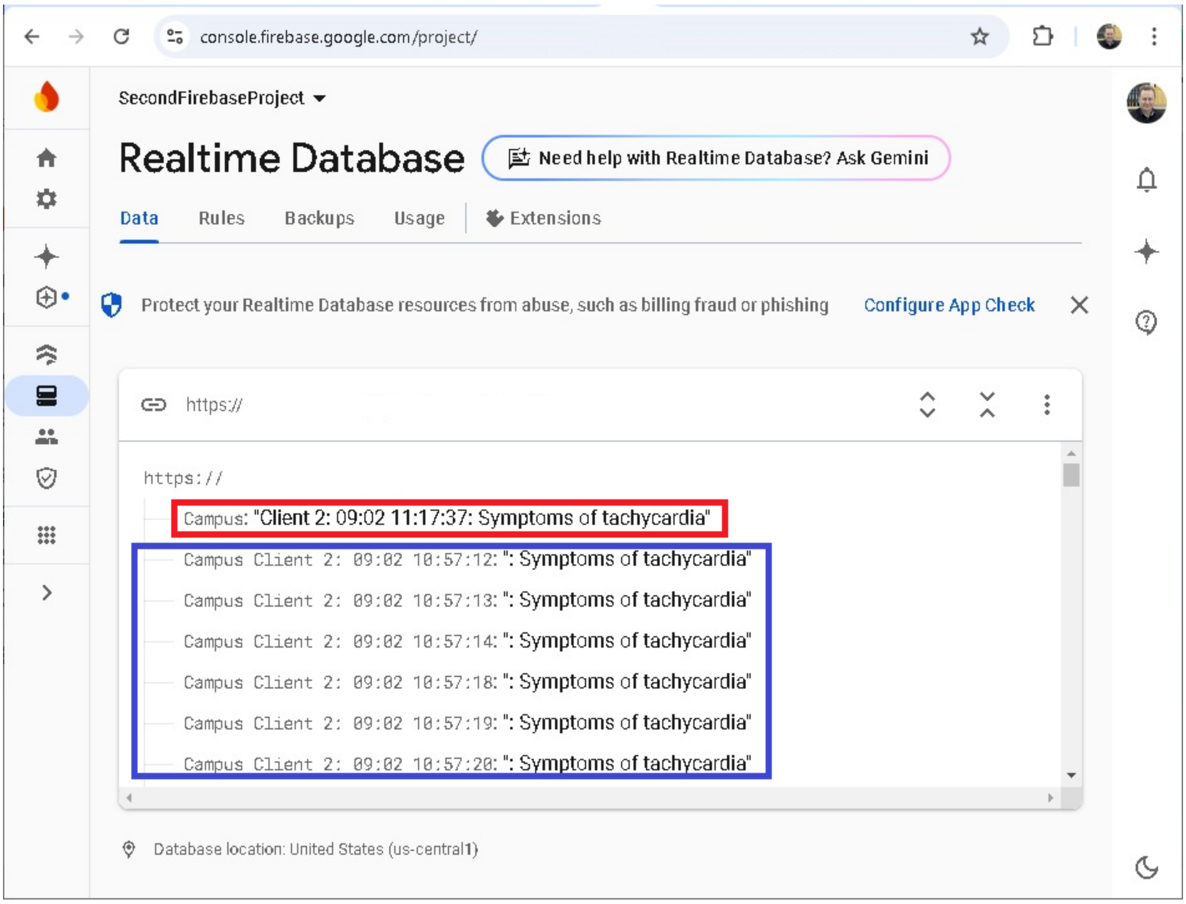


Figure 4: An example of the Firebase console with information from the user named "Client 2".

The second type of nodes employs the following format to transmit data to the Firebase Realtime Database:

[Username]: [Date dd:mm] [Time hh:mm:ss]: [Vital parameter]

The location of individual(s) is not identified in this project due to specific privacy requests from the experiment participants. However, the individual can be easily located on the Naryn campus by security if necessary.

4. Heart emergency SOS project: experiment at the Naryn campus of the University of Central Asia

This study was inspired by the real-life issue of a 52-year-old co-author Mr. Dmytro Zubov, who experienced tachycardia while on the Naryn campus of the University of Central Asia. Figure 5 illustrates an example of his electrocardiogram (ECG) with a resting heart rate of 100 beats per minute. The data was collected during the regular annual medical checkup of teaching staff. It is classified as tachycardia for adults, though it is a common response in high-altitude mountain regions. Mr. Zubov typically has a normal resting heart rate of 60 beats per minute at an elevation of 800 m in Bishkek city.

The experiment conducted on the Naryn campus demonstrates that the smartwatch application correctly identifies the tachycardia of Mr. Dmytro (see Figure 6, A and the red rectangle in Figure 4) using a Samsung Galaxy Watch 4 40 mm. The false alarm situation, when the smartwatch application starts and displays a heart rate of zero beats per minute, is presented in Figure 6, B. Figure 6, C depicts the smartwatch screen without any abnormal detection. All measurements presented in Figure 6 were taken by a 52-year-old Mr. Dmytro Zubov.

In this study, software reliability [22] is the probability of failure-free operation while the customer uses the smartwatch. The software developer Mr. Dmytro Zubov was using a smartwatch application for ten days without any failure. Figure 7 shows an example of binary data, symptoms of tachycardia are present (1) or absent (0), continuously collected on February 12, 2025, from 10:57 am to 11:30 pm, on the Naryn campus.

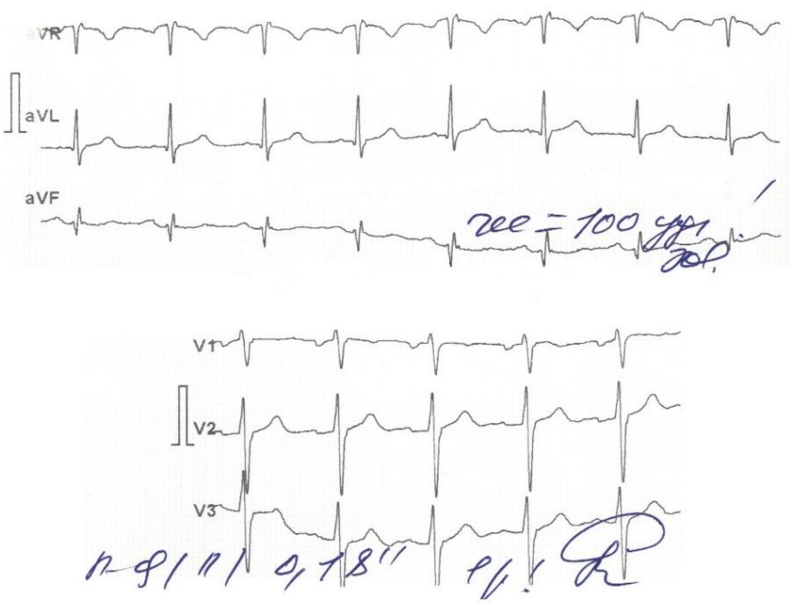
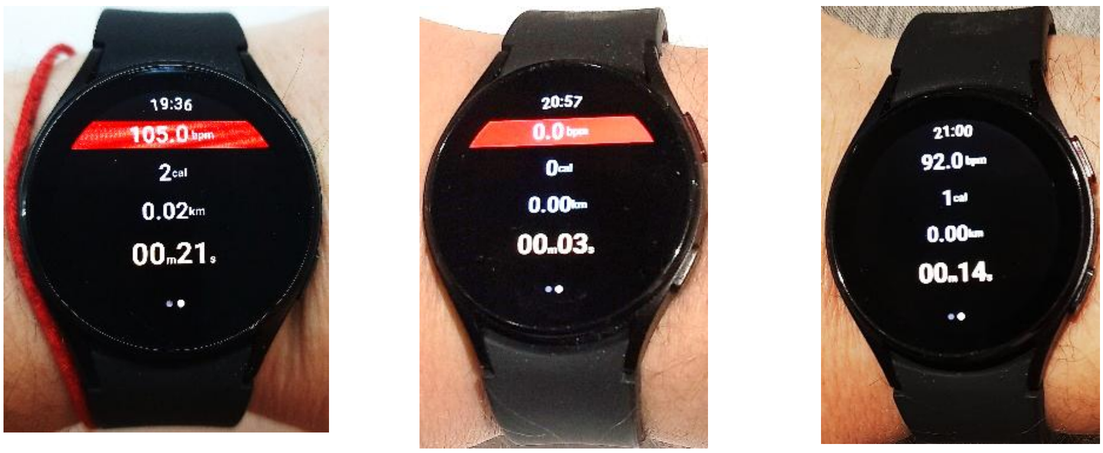


Figure 5: An example of an ECG with a resting heart rate of 100 beats per minute, which indicates tachycardia. This ECG was recorded at the Naryn campus, situated at an elevation of approximately 2000 m, and it belongs to a 52-year-old Mr. Dmytro Zubov.



a) b) c)

Figure 6: Examples of Samsung Galaxy Watch 4 40 mm screens showing tachycardia (A), risk of cardiac arrest (B), and no abnormal detection (C).

Three more people took part in the experiment: a 49-year-old female, a 22-year-old female, and a 23-year-old male. The achieved results demonstrate that the smartwatch application functions correctly, while individuals are either sitting or jogging.

Currently, cases of cardiac arrest have not been documented, and incidents of tachycardia, such as those experienced by Mr. Dmytro Zubov, are single instances at the Naryn campus of the University of Central Asia. In the future, statistics related to the prevalence and incidence [23] of heart problems are planned to be calculated as follows:

1. Prevalence:

$$\frac{\textit{number of cardiac arrest / tachycardia cases on the university campus at one time}}{\textit{number of the university campus inhabitants at the same point of time}} \qquad (1)$$

2. Incidence:

$$\frac{\textit{number of new cases of cardiac arrest / tachycardia during a specified time period}}{\textit{number of the university campus inhabitants at the start of a specified time period}} \qquad (2)$$

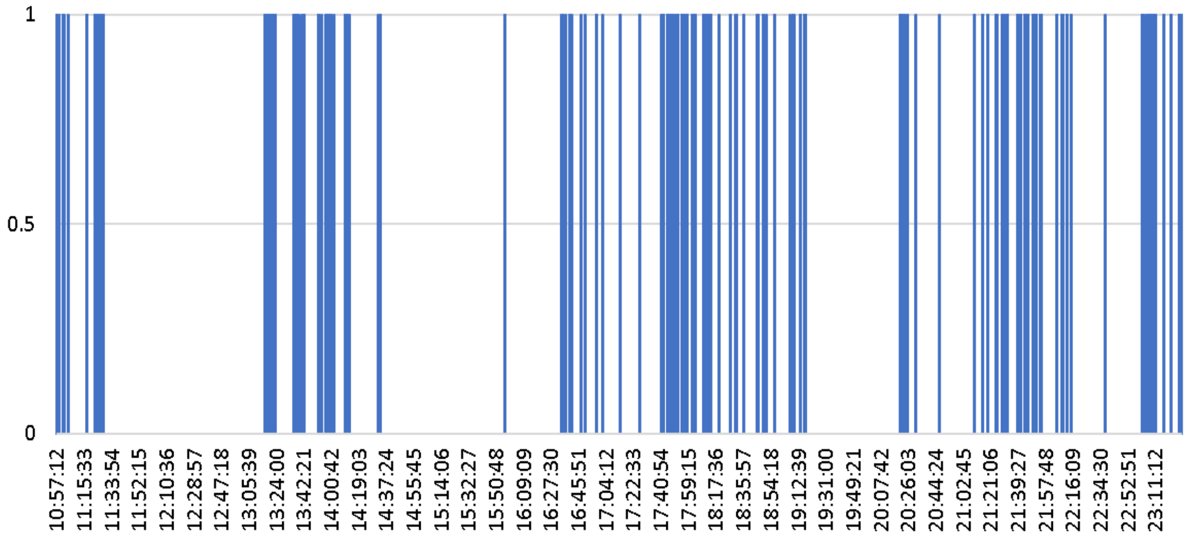


Figure 7: An example of binary data, symptoms of tachycardia are present (1) or absent (0), continuously collected by the software developer Mr. Dmytro Zubov on 12th February 2025, from 10:57 am to 11:30 pm, on the Naryn campus.

5. Results and discussion

This study presents a heart emergency SOS system prototype built with Samsung Galaxy Watch 4 40 mm smartwatches connected via the Firebase Realtime Database. The project was tested successfully on the focus group of four people, and the tachycardia was correctly identified for one participant (others do not have such a heart issue). The testbed was the Naryn campus of the University of Central Asia, situated at an elevation of about 2000 m. Campus doctors and other qualified experts can access the data remotely via the Firebase console and/or custom software such as a mobile application. Hence, the presented soft-/hardware complex enables the acquisition and analysis of remote data from multiple users.

During the discussion of the project presented at the Department of Computer Science of the University of Central Asia and at the Department of Computer Systems and Networks of the Kryvyi Rih National University, two questions were raised:

1. WearOS is used worldwide for Google Android-based smartwatches. However, another large segment of the market is occupied by watchOS, which is employed by Apple Watch. The recommendation was to explore the implementation of presented ideas on watchOS as well.
2. The smartwatch applications were developed using the Kotlin programming language and the Jetpack Compose declarative paradigm. Although these are innovative approaches, it was suggested to consider using classical imperative programming paradigms to enhance code readability for other developers.

In addition, the Gemini generative artificial intelligence chatbot [24] was requested to provide recommendations on what should be improved in the research (see Figure 8) on March 4, 2025. The response included five parts:

1. Expand the section “Related Works”: include more diverse wearable solutions; discuss different communication protocols; highlight the limitations of existing solutions; incorporate studies focusing on high-altitude health monitoring.
2. Strengthen the section “Methods”: provide more details about the data collection process; explain the criteria for tachycardia and cardiac arrest detection; address ethical considerations; consider including a control group.
3. Enhance the section “Results and Discussion”: present more comprehensive data; discuss the limitations of the study; explore the implications of your findings; incorporate a more detailed comparison with other studies.
4. Refine the presentation: proofread carefully for grammar and spelling errors; ensure consistent formatting throughout the paper; consider adding a table of abbreviations; visually enhance figures and tables; provide more context for the ECG in Figure 5.
5. Expand the scope and future work: explore the possibility of integrating other vital signs; investigate the use of machine learning algorithms; consider the development of a more user-friendly interface; discuss the potential for commercialization and wider adoption.

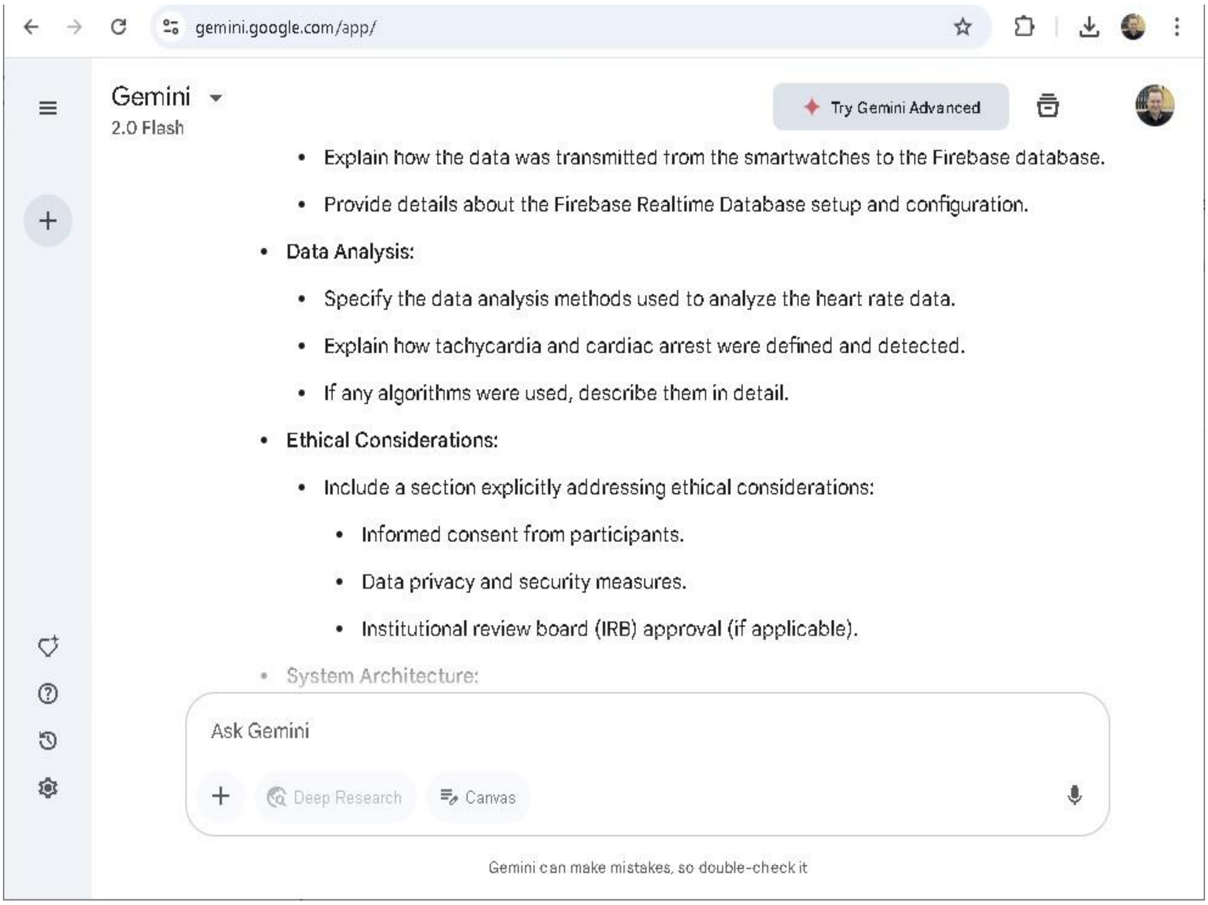


Figure 8: The screenshot of the response (a part) of the Gemini generative artificial intelligence chatbot on the request to provide recommendations on what should be improved in the research.

Some of the above-stated recommendations, such as addressing ethical considerations (the informed consent was obtained from Mr. Dmytro Zubov to use his data), have already been considered. Other suggestions are not critical in the presented study, and hence they can be taken into account in future work.

6. Conclusions

In this study, the prototype of the heart emergency SOS system was developed with Samsung Galaxy smartwatch 4 40 mm and Firebase Realtime Database in the context of the Healthcare 5.0 patient-centered approach. This project aims to extend the functionality of existing commercial solutions, such as standard healthcare smartphone applications, which usually send data to connected smartphones within a personal area network only. Users wear smartwatches to measure their heart rates, which are then transmitted to the cloud-based Firebase Realtime Database. This data can then be accessed by campus doctors and other qualified experts directly from the Firebase console and/or via custom software such as a mobile application. The current version considers two vital parameters: the tachycardia and the risk of cardiac arrest.

An experiment conducted on the Naryn campus of the University of Central Asia (elevation is approximately 2000 m) demonstrates that the smartwatch application correctly identifies abnormal states of vital parameters in a focus group of four people.

The most likely prospects for further development of the presented study are as follows: expand the number of vital parameters analyzed by smartwatch applications and investigate the use of machine learning algorithms.

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Declaration on Generative AI

During the preparation of this work, the authors used the Grammarly writing assistant [25] to check grammar/spelling and the Gemini generative artificial intelligence chatbot to discuss the results of the presented study. After using these tools, the authors reviewed and edited the content as needed. The authors take full responsibility for the content of this publication.

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