Digital Health in Africa: Challenges and Research Opportunities

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About me

Director: UCT Telkom Centre for Broadband Networks and Applications

Co-founder: UCT Sentech 5G Centre for Sensors, Communication, Blockchain & AI for Sustainable Development

Founding member: UCT African Robotics Unit

Member: Telemedicine and Connected Care Group at UCT

Convener: 5G Research and Development Working Group at ICASA (Independent Communications Authority of South Africa) 5G Forum

Secretary: IEEE South Africa Section Executive Committee

Member: IEEE ComSoc Women in Communications Engineering

Healthcare Challenges in Africa

- Africa bears a disproportionate burden of disease and death due to HIV/AIDS, malaria and tuberculosis
- Further disadvantaged by neglected tropical diseases, and non-communicable diseases

Sub-Saharan Africa is home to 53% of HIV-positive people worldwide
(United Nations, 2018)

90% of the estimated 300–500 million malaria cases occur in Africa, mainly in children under the age of five (World Health Organization, 2014)

Healthcare Challenges in Africa

- Health care systems in Africa are plagued by inefficiencies; they are overstretched, under-resourced, and have limited number or poor distribution of skilled healthcare workers
- Inadequate systems for health management, such as in procurement, service delivery, and monitoring of clinical and programme outcomes
- In general, lack of access is the greatest challenge to healthcare delivery, with fewer than 50% of Africans having access to modern healthcare facilities

In South Africa 79% of doctors work in the private sector, which is accessible to only 16% of the population; the doctors working in government and public facilities then also prefer to work in cities. This leaves more than 50% of citizens residing in rural areas with limited or no access (Health Systems Trust, 2018)

Digital Health

- Digital health is seen by many as a solution to a number of these issues
- Digital health technologies rely on the availability of Internet connectivity to function effectively
- Africa largely lacks fixed-line network infrastructure in rural and semi rural regions, combined with the poor quality of the networks available in urban areas

Structural Challenges

- A straightforward route to wide deployment and adoption of digital health systems in Africa is not clear
- Most African countries do not have stable electricity grids, and of the one billion people in the world that lack access to electricity, 634 million reside in sub-Saharan Africa. *(Farquharson, 2018)*
- Another challenge is the inferior and degraded internet connectivity infrastructure outside of urban areas *(GSMA, 2021).*

Opportunities

- Mobile network infrastructure is the dominant connector of Internet users, mobile technologies (3G and 4G) account for 90–98% of all internet connections in most African countries *(BuddeComm, 2018)*
- Smart digital healthcare systems could readily use existing cellular networks and other communication technologies

5G-enabled digital healthcare systems

Impact potential 1: foster the development of relevant digital health technologies and services.

The uptake of ICT, such as the use of 5G technology, the Internet of Things, low cost computing and mobile applications, in African clinics and hospitals is currently very limited. Common digital health platforms that are low cost and well documented could be re-used at different locations, to lower the barrier to entry for such technologies in Africa.

5G-enabled digital healthcare systems

Impact potential 2: identify technologies corresponding to specific needs of target regions for economic and societal impact.

One outcome of developing unified digital health platforms is to stimulate the creation of locally relevant digital health applications, with the health platforms acting as common hubs for local users and developers.

5G-enabled digital healthcare systems

Impact potential 3: identify barriers, obstacles or conditions that may influence the adoption of digital health platforms and applications.

Our vision of 5G-enabled digital health in Africa is ambitious and would face many barriers before it becomes a reality, such as overcoming different national regulations, or lack of resources and infrastructure within a particular region. The deployment of 5G-enabled digital health platforms needs to consider and adapt to these barriers.

5G-enabled digital healthcare systems

Impact potential 4: improved public health.

The establishment of 5G digital health platforms would support UNSDG 3, improving and ensuring the health of all citizens through strengthening healthcare services in rural communities, where the majority of citizens reside in developing countries. For example, applications for health screening, remote diagnoses, remote patient monitoring and remote training of healthcare staff could be developed and validated.

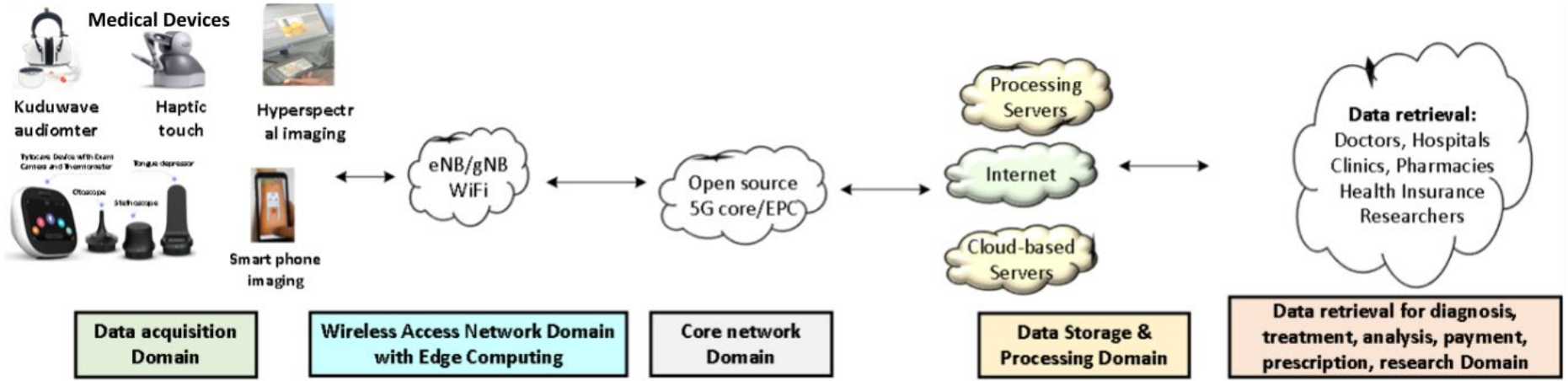
Our Research Aim

We want to develop a secure and intelligent 5G digital health testbed for evaluating and validating Telemedicine and Digital Health applications in Africa

Motivations

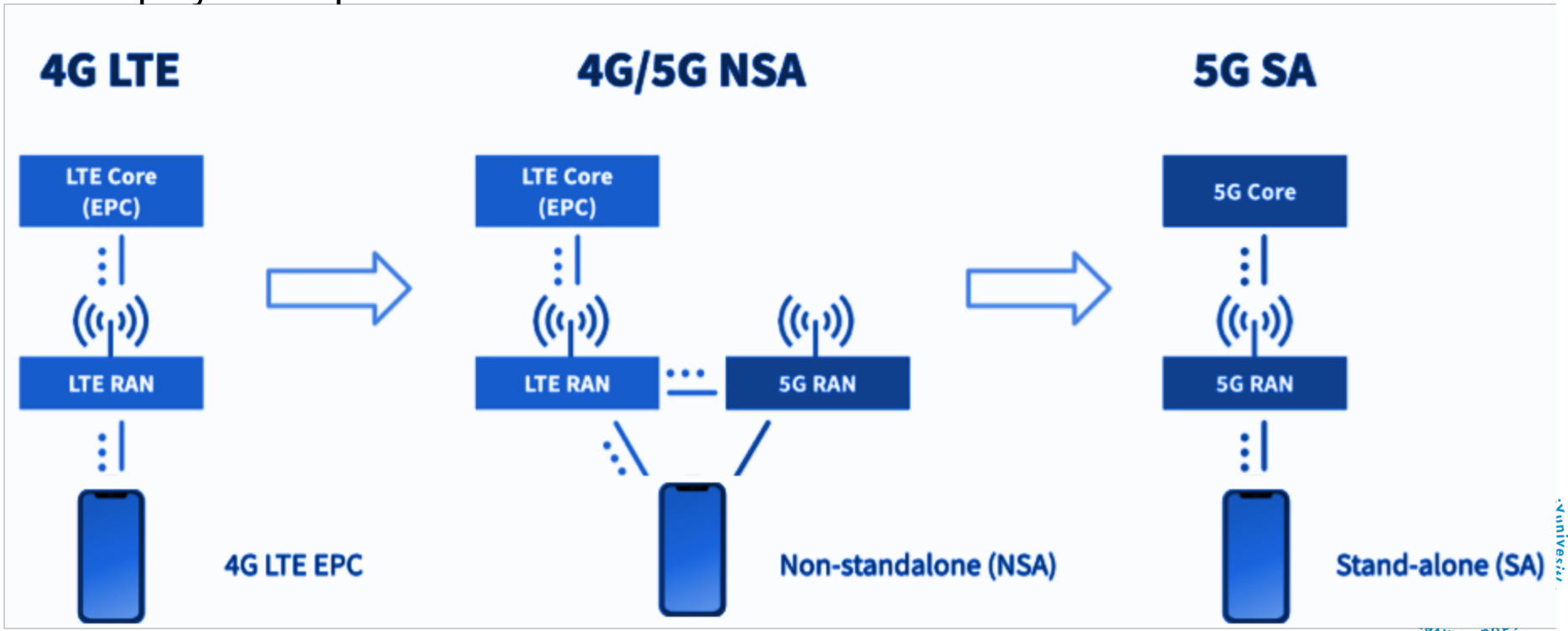
- Create a state-of-the-art platform for validation of digital health applications
- Drive adoption of digital health solutions in mainstream health systems

5G-enabled Digital Health System Architecture



5G Experimental Testbeds

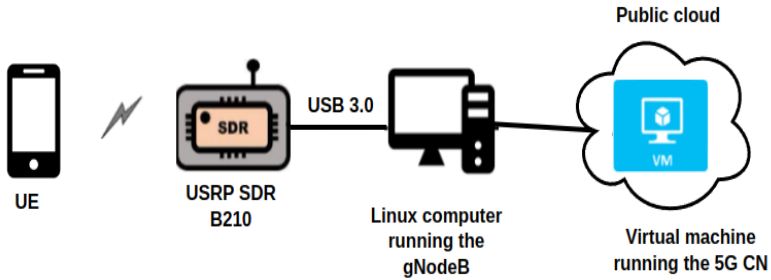
5G deployment options



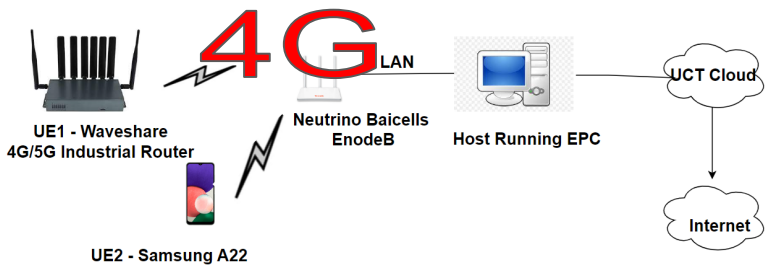
5G Experimental Testbeds

We have deployed real over the air testbeds using SDRs, mobile phones and open source networking stacks including:

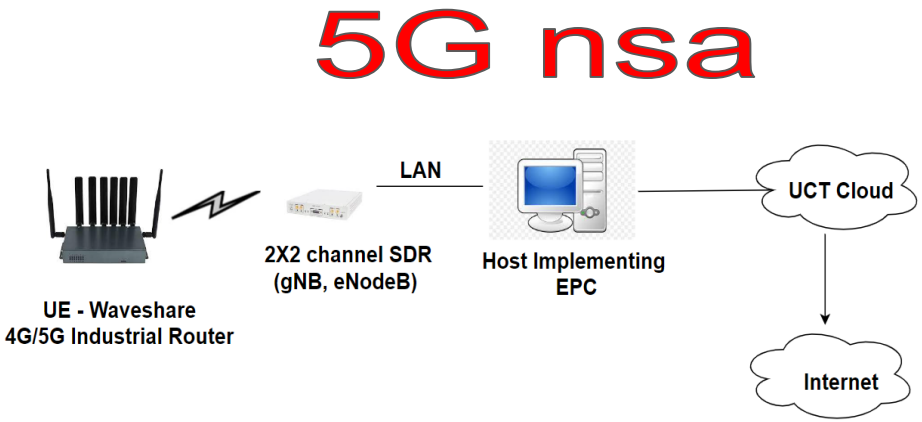
- Open Air Interface
  - Both radio and core network stacks
  - Both in 5G non standalone and 5G standalone
- Software Radio Systems
  - Radio network stack only
  - 4G, 5G NSA and 5G SA (working with other cores)
- Open 5G Systems
  - Core network stack only
- Free 5G Core
  - Core network stack only



5G Experimental Testbeds



M Chepkoech et al. " Evaluation of Open-Source Mobile Network Software Stacks: A Guide to Low-Cost Deployment of 5G Testbeds" 18th Wireless On Demand Network Systems and Services Conference (WONS), Madonna di Campiglio, Italy, January 2023.

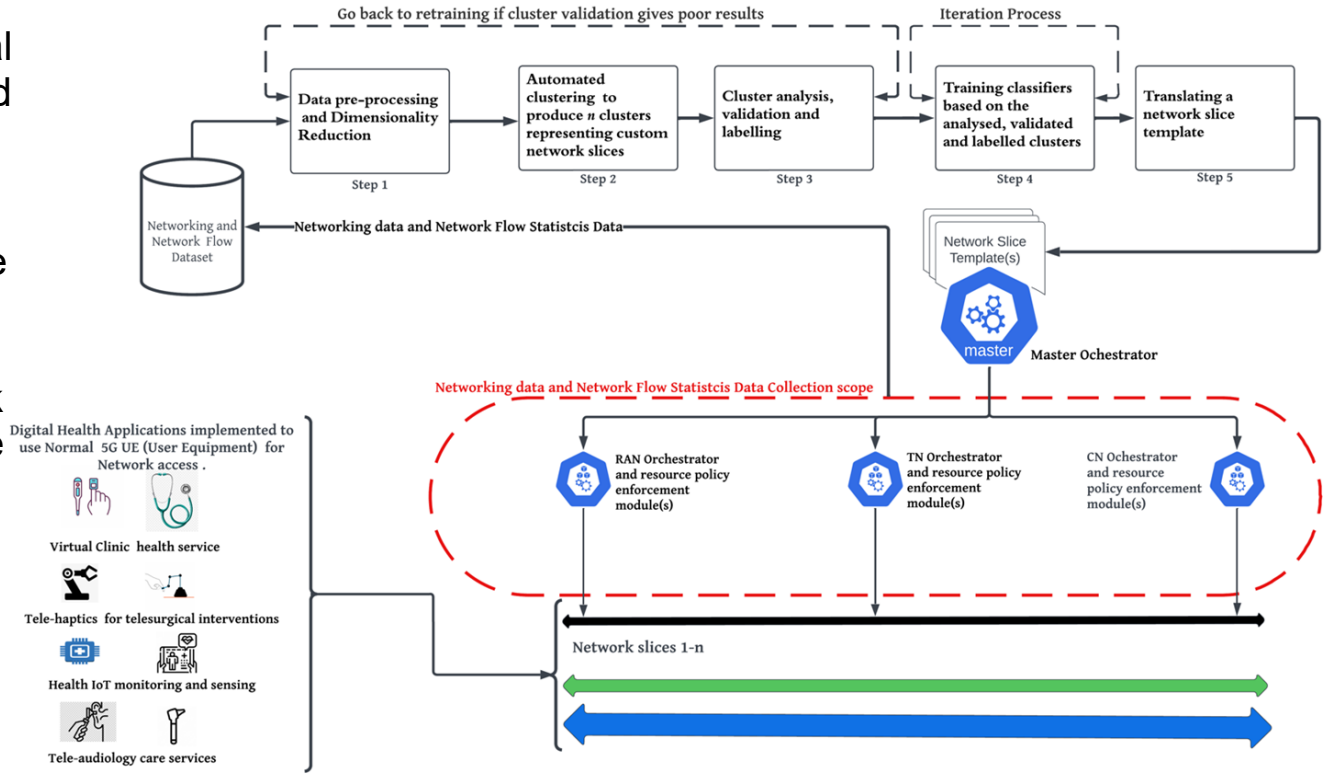


M. Chepkoech et al., "Evaluation of OSS-Enabled OpenRAN Compliant 5G StandAlone Campus Networks," 2023 International Conference on Electrical, Computer and Energy Technologies (ICECET), Cape Town, South Africa, 2023

5G Digital Health Testbed

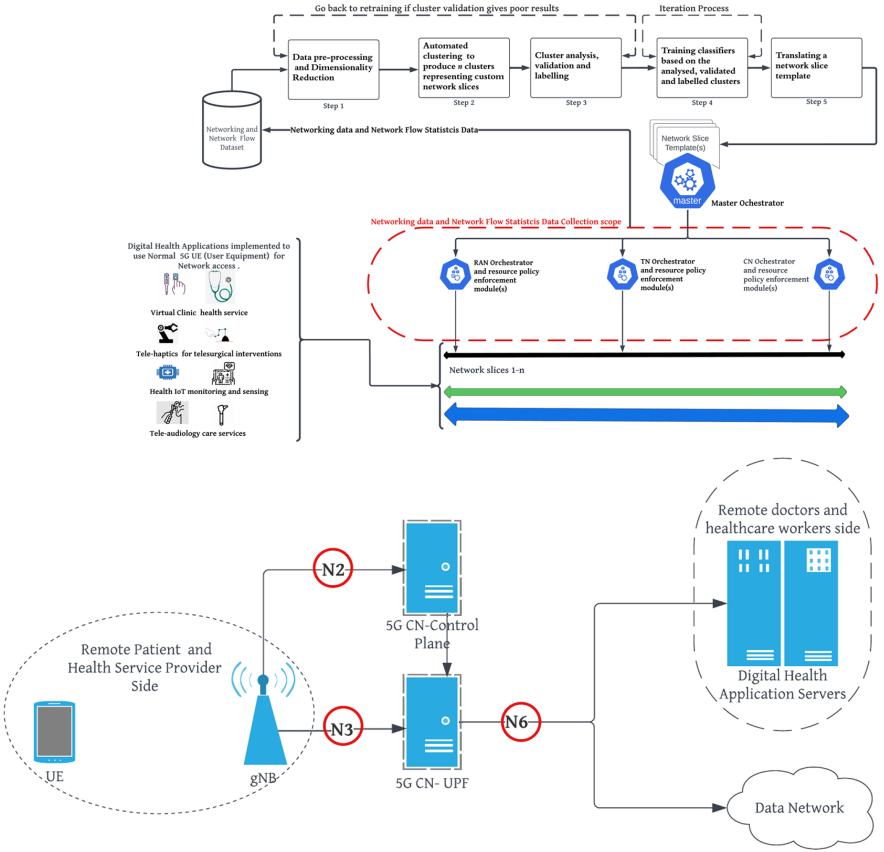
Implement an end-to-end 5G test network for various digital health applications connected to the 5G test network.

Design, implement, and evaluate end-to-end resource orchestration, management, and enforcement framework that uses the custom network slice templates to orchestrate the end-to-end network slice instances.



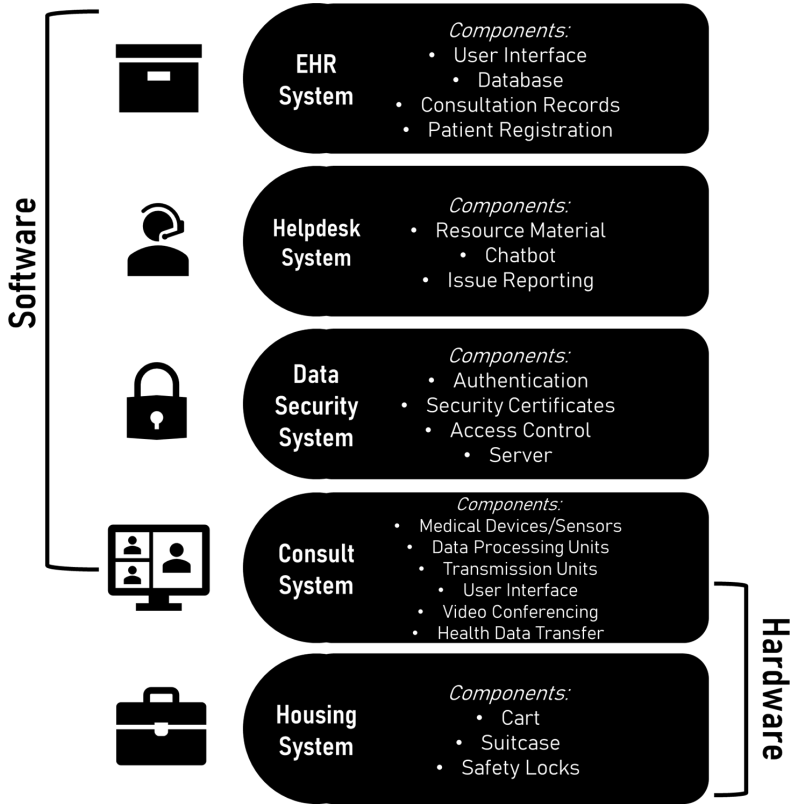
5G Digital Health Testbed

H. Owuor et al. “A Strategy to Develop and Translate Custom 5G Network Slice Templates using Machine Learning Techniques”, IEEE AFRICON 2023, 20-22 September 2023, Nairobi, Kenya.



Virtual Clinic System

- Followed a “user-centred design” approach
- Implemented and evaluated a virtual clinic system suitable for communities in remote, rural, and underserved areas
- Extensive evaluation and usability testing
  - Network performance
  - Usability testing with 10 doctors and 11 nurses

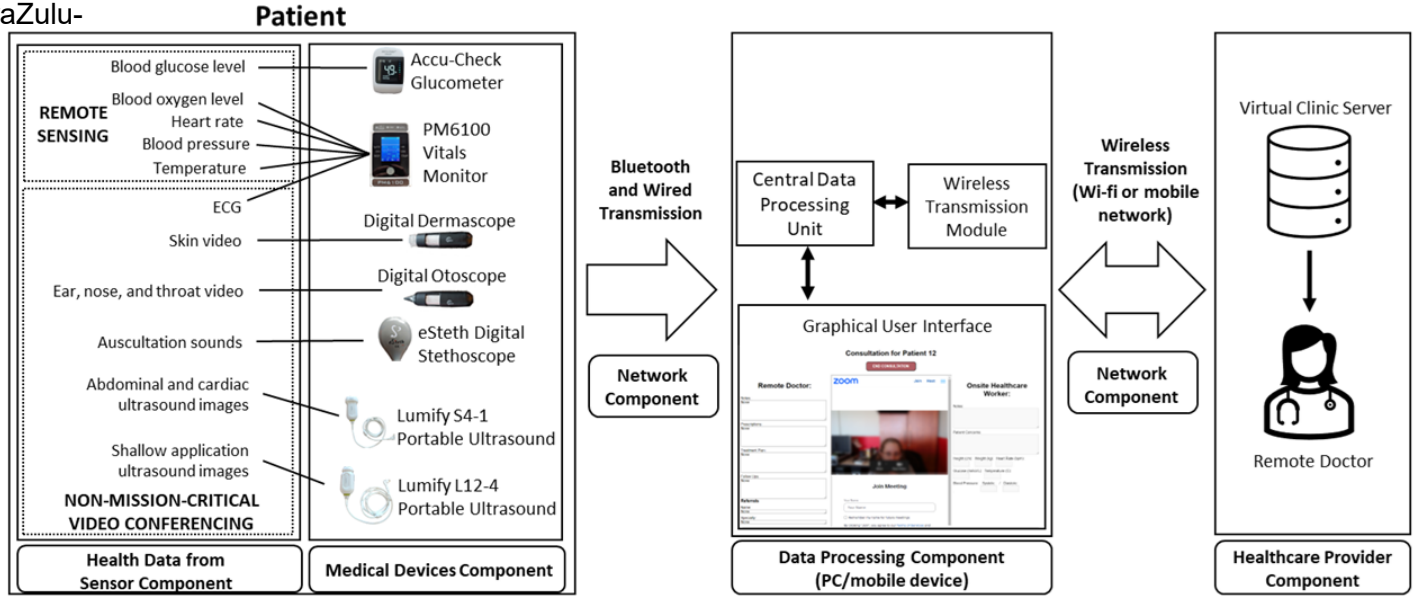


Virtual Clinic

A. Blocker et al. “Evaluation of the Capabilities of a 3G Mobile Network to Support a Virtual Clinic System in Rural Sub-Saharan Africa”, Southern African Telecommunications Networks and Applications Conference (SATNAC) 2023, Central Drakensberg, KwaZulu-Natal, South Africa, August 2023.

A. Blocker et al. , “Development of a telemedicine virtual clinic system for remote, rural, and underserved areas using user-centered design methods”, DIGITAL HEALTH, October 2023 (under review).

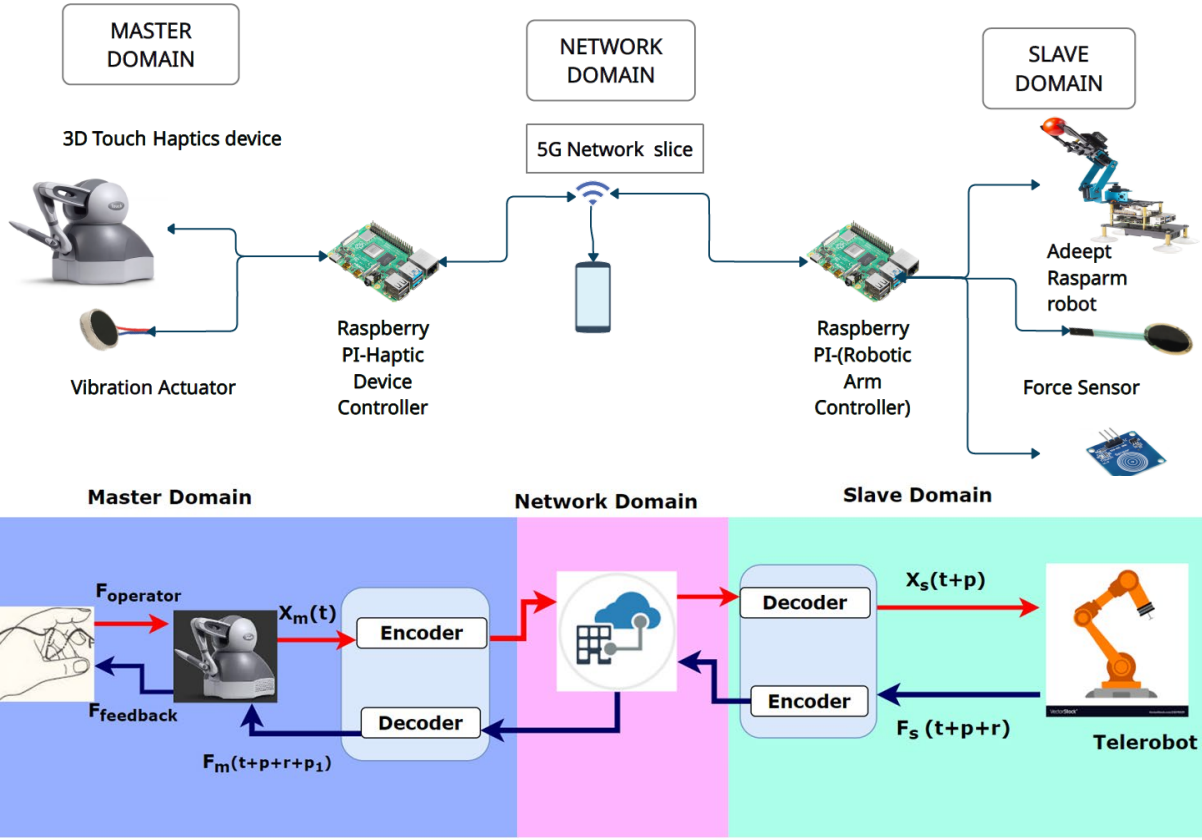
A Blocker et al. “Evaluating the capability of 3G, 4G, and 5G networks in delivering a virtual clinic solution” IEEE AFRICON 2023, 20-22 September 2023, Nairobi, Kenya.



Towards low-cost 5G-powered Telerobotic surgery

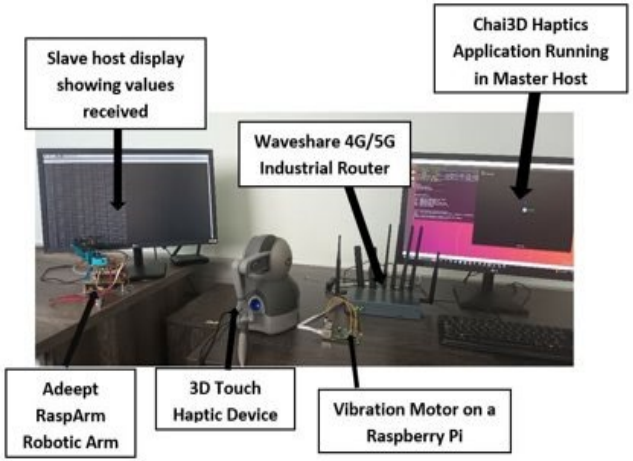
Telehaptics system enables the generation and transmission of touch sensations between distant locations.

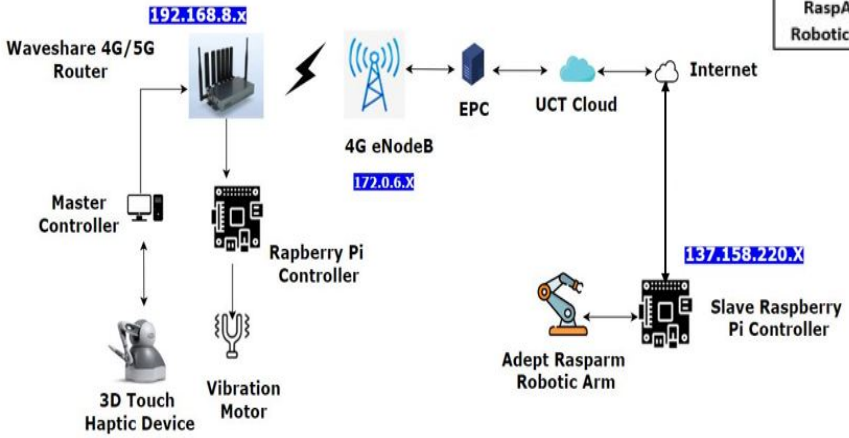
Key requirements include low latency, consistent and stable haptic control, reliable haptic control over the network.



Towards low-cost 5G-powered Telerobotic surgery

M. Chepkoech, et al. “Implementation and Evaluation of Telehaptics over Long Term Evolution (4G) - Towards 5G Powered Telesurgery” IEEE Conference on Standards for Communications and Networking (IEEE CSCN), 28 – 30 November 2022, Thessaloniki, Greece.



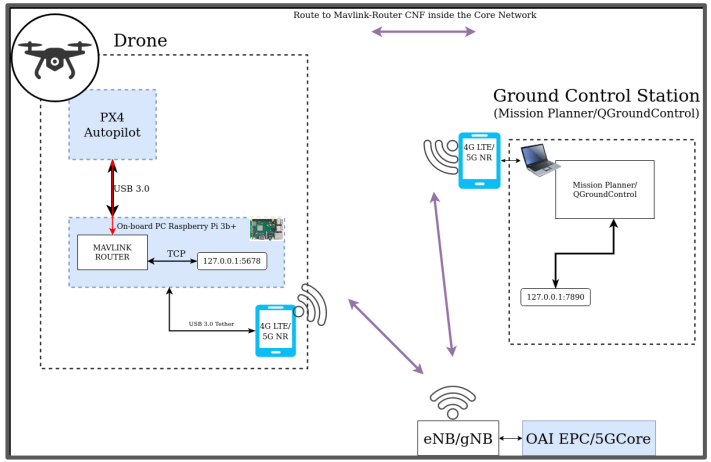


Other recent publications

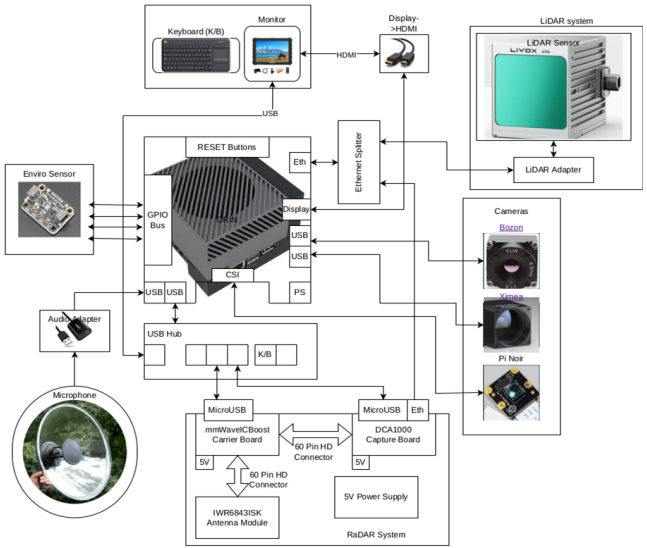
1. J. Mwangama et al. “What can 5G do for healthcare in Africa”, Nature Electron, Volume 3,
2. A. Kaliwo et al. “Implementation and Evaluation of a Tele-Audiology System on a Digital Health Testbed Based on a 5G Non-standalone Technologies”, in the 2nd International Conference on Electrical, Computer, Communications and Mechatronics Engineering (ICECCME 2022), 16 – 18 November 2022, Maldives.
3. H. Otieno et al “Towards Simple, Efficient and Centralized Log Monitoring, and Analysis of 5G Core Loud-Native Network Functions”, SATNAC 2022, 28-30 August 2022 , George, South Africa. .
4. L. Mamushiane et al. “Towards Stress Testing Open5GS Core (UPF Node) On A 5G Standalone Testbed," 2023 IEEE AFRICON, Nairobi, Kenya, 2023
5. L. Mamushiane, et al. "Deploying a Stable 5G SA Testbed Using srsRAN and Open5GS: UE Integration and Troubleshooting Towards Network Slicing," 2023 International Conference on Artificial Intelligence, Big Data, Computing and Data Communication Systems (icABCD), Durban, South Africa, 2023
6. L. Mamushiane, et al. “Experience in Profiling and Optimizing A 5G StandAlone Radio Access Network (RAN) Based on an Open Source Testbed”, Southern African Telecommunications Networks and Applications Conference (SATNAC) 2023, Central Drakensberg, KwaZulu-Natal, South Africa, August 2023

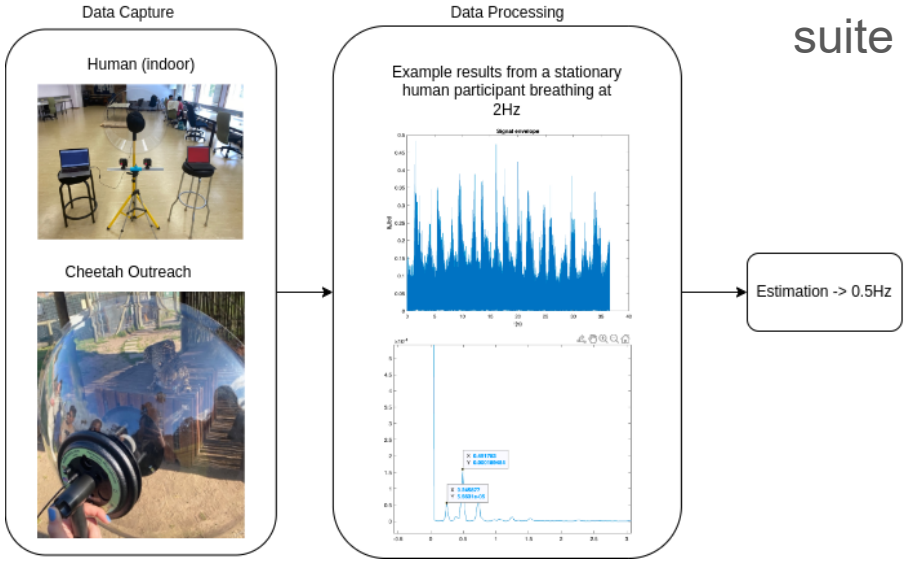
Works in Progress and Future Research

- AR and Tele Haptics for remote surgery
- 5G Smart Ambulance for emergency telemedicine
- OpenRAN and 5G+ / 6G
- Building a commercial grade test lab (in talks with Nokia)



- Robotics: UAV communications, unmanned ground vehicles
- Wildlife monitoring: Multi-modal sensor suite

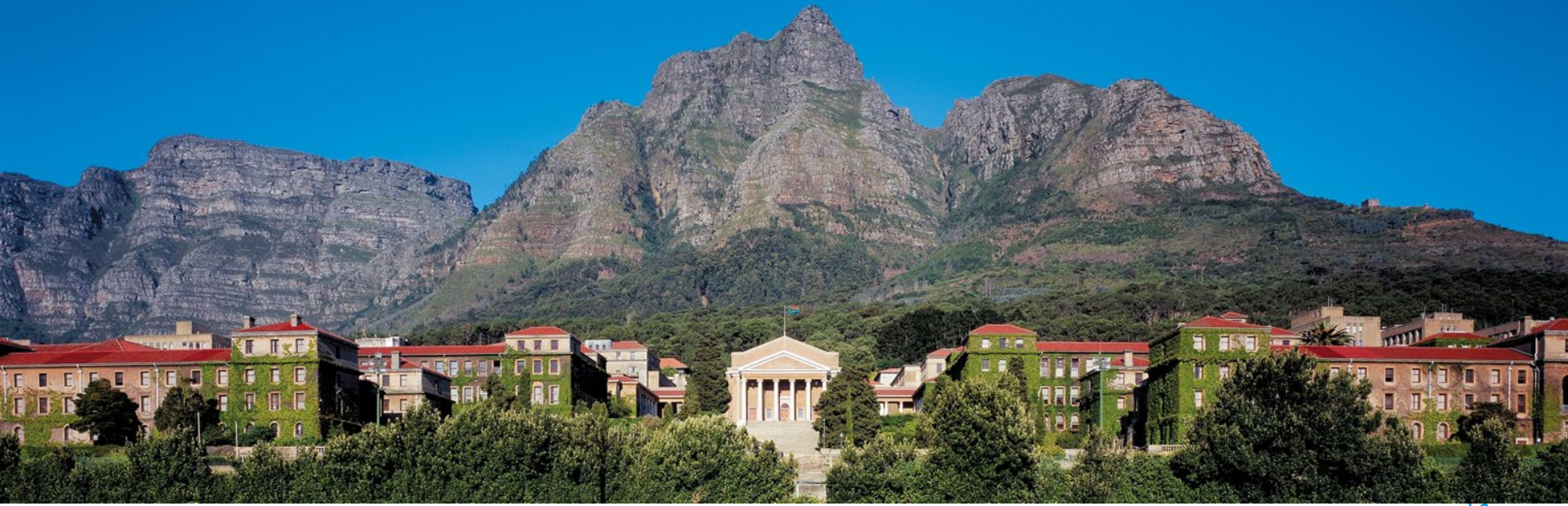




5G and beyond research at UCT

- Funders:
  - Telkom
  - Sentech
- Collaborators:
  - Fraunhofer FOKUS
  - Technische Universität Berlin
  - University of Oulu
  - Council for Scientific and Industrial Research

Thank you!



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