Towards a 5G & Haptic-Enabled Internet for Remote Robotic Surgery: A Task-Technology Fit (TTF) Model

Dr Maradona C. Gatara, PhD || Prof Mjumo Mzyece, PhD || Prof Sijo J. Parekattil, MD

WWRF 45, Kuala Lumpur, Malaysia, 18 – 21 January 2021

WITS UNIVERSITY | Wits Business School

UCF College of Medicine, University of Central Florida | AVANT Concierge Urology

WIRELESS WORLD RESEARCH FORUM®

Outline

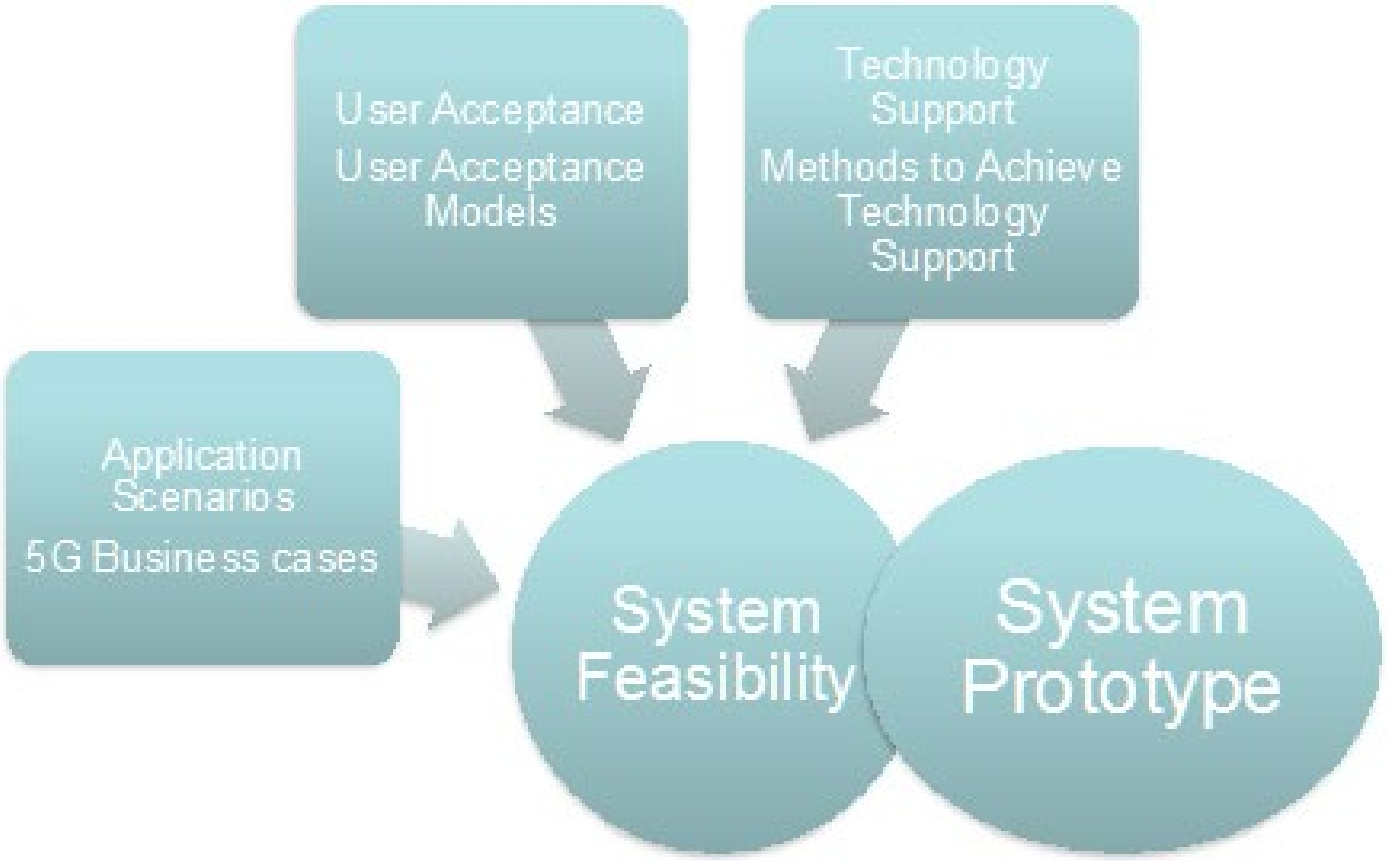
1) **Executive Summary**
2) **Context**
3) **5G & Haptic Internet for Remote Robotic Surgery**
4) **TTF & TTF Model**
5) **Methodology**
6) **Contributions & Future Work**
7) **Conclusions**

1) Executive Summary
Main messages on one slide

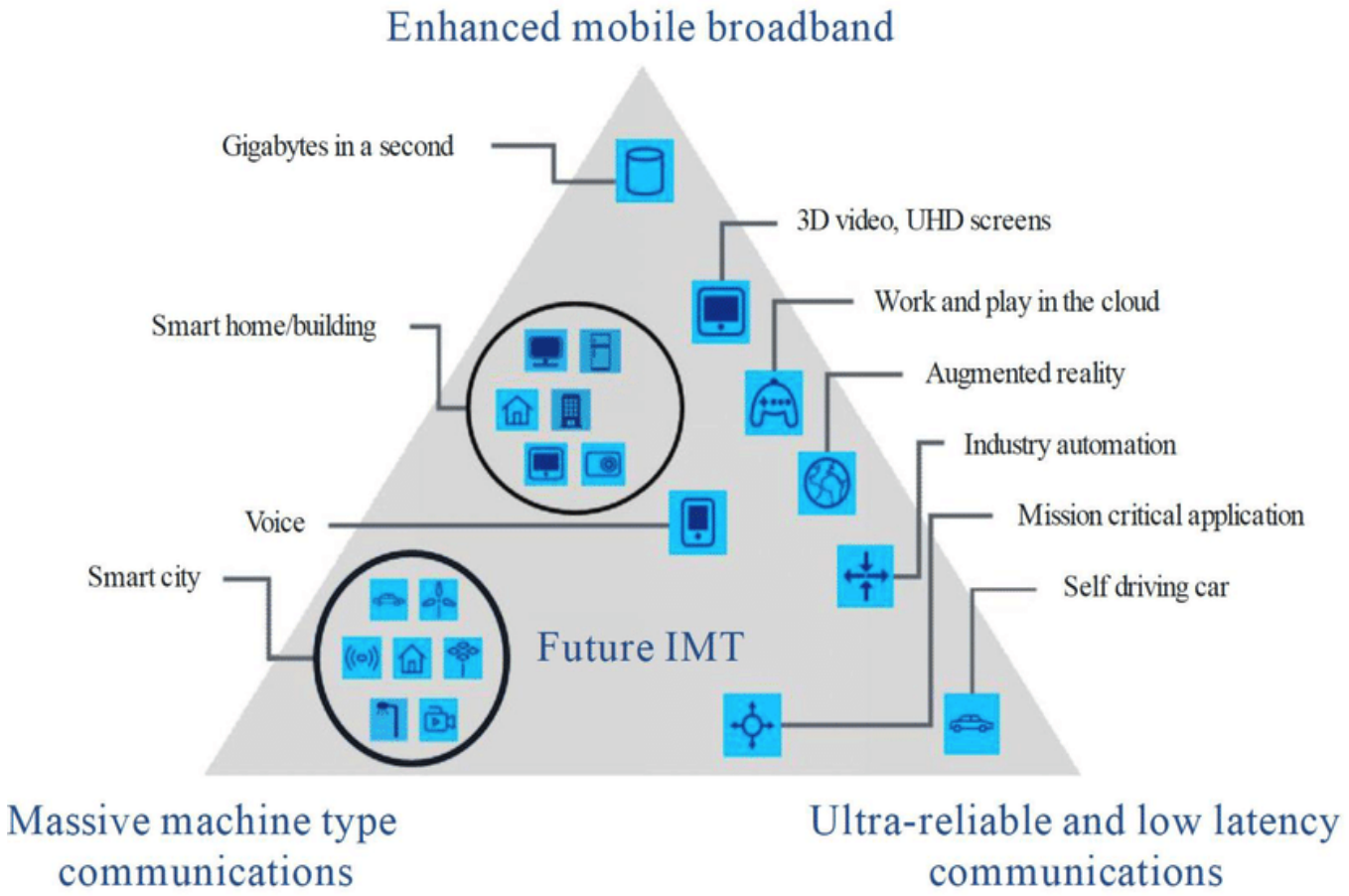
- We need to explore the “fit” between technologies and end-user tasks to create better services
- Shift from QoS to QoE + QoT
- Task-technology fit (TTF) based R&D is promising to support this new direction
- Potentially extensible to other human in the loop (HITL) scenarios
- Broadly applicable to 5G and Beyond 5G networks

2) Context
WWRF 45 (conference theme)

2) Context
VIP WG 5G e/m-Health and Wearables (session focus)



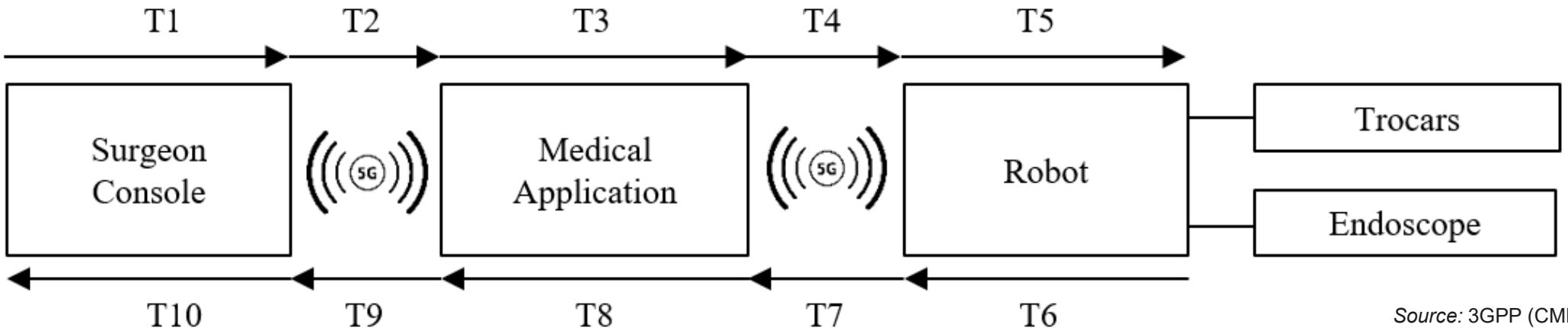
2) Context
5G Use Cases and Applications



Source: ITU-R (2015)

3) 5G & Haptic Internet for Remote Robotic Surgery

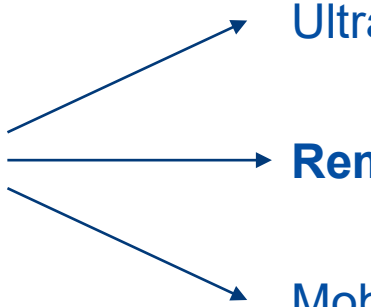
Local and remote robotic surgery scenarios



Source: 3GPP (CMED, TR 22.826)

3) 5G & Haptic Internet for Remote Robotic Surgery
Critical medical applications use cases (modalities)

1. Static – Local
2. **Static – Remote**
3. Moving – Local
4. Moving – Remote



- Ultrasound examination & remote interventional support
- **Remote robotic surgery**
- Mobile specialist practice

Reference: TR 22.826 (CMED, 3GPP)

3) 5G & Haptic Internet for Remote Robotic Surgery
Technology standards (illustrative, not exhaustive)

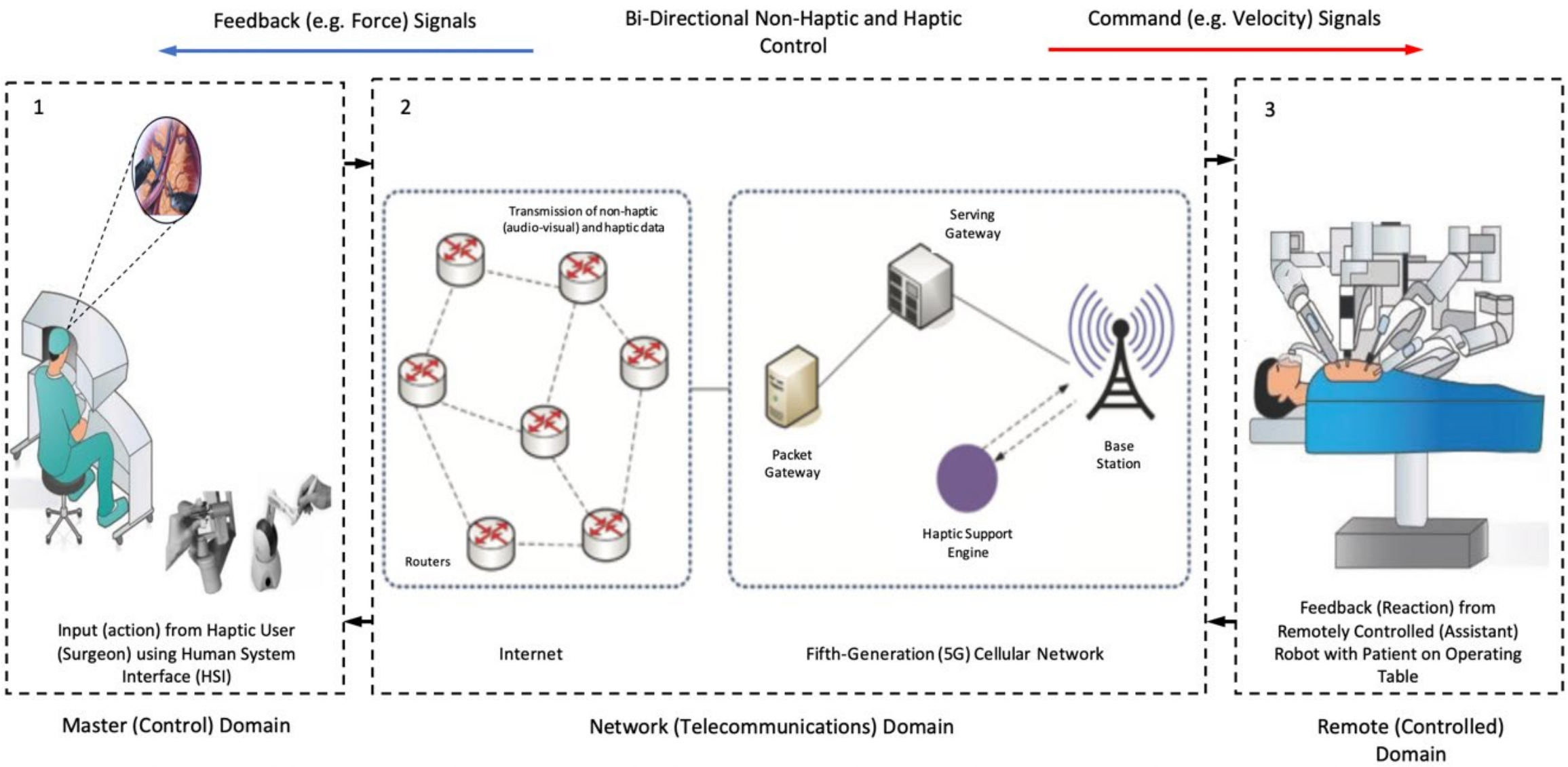
Standards	**Standards bodies**
Study on Communication Services for Critical Medical Applications (CMED) | TR 22.826	3GPP
Service requirements for the 5G system | TS 22.261	3GPP
Service requirements for cyber-physical control applications in vertical domains | TS 22.104	3GPP
Service requirements for video, imaging and audio for professional applications (VIAPA) | TS 22.263	3GPP
Digital Imaging and Communications in Medicine (DICOM) | ISO 12052	MITA/NEMA
Precision Time Protocol (PTP) | IEEE 1588	IEEE
Application of risk management for IT-networks incorporating medical devices | IEC 80001	ANSI, AAMI, IEC
⋮	⋮
many others (cybersecurity, etc.)	*various*

Reference: TR 22.826 (CMED, 3GPP)

3) 5G & Haptic Internet for Remote Robotic Surgery
Human in the loop (HITL): From QoS to QoE + QoT

- **Human in the loop (HITL)** aspects of 5G / Haptic Internet will be the essential link between surgeons and patients in remote environments.
- **Quality of Experience (QoE)** for the development of task performance metrics.
- **Quality of Task (QoT)** as a measure of the precision with which a user can perform tasks with given technological support functions.

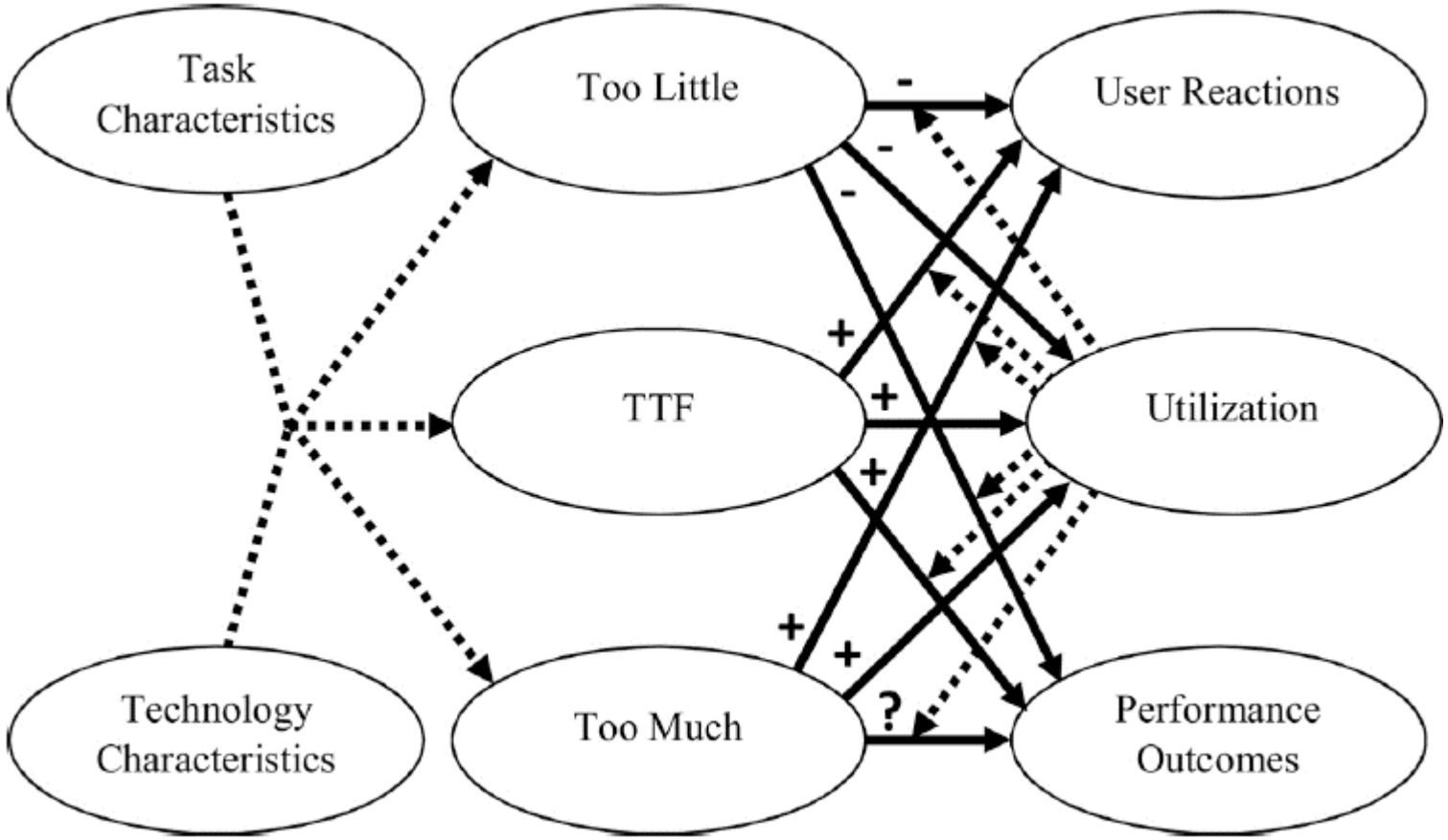
3) 5G & Haptic Internet for Remote Robotic Surgery
System architecture



4) TTF & TTF Model
Task-Technology Fit (TTF) Theory

- **Task-Technology Fit (TTF)** is the degree to which the functional capacity of a technology tool or system meets the user needs or activity demands of a particular task or set of tasks.
- **Utilisation** and **performance** impacts will result from the presence of a task-technology fit. Thus, TTF is linked to **use** and **user task performance**.
- TTF influences use and performance because a technology tool or system will be used in performing a task or **tasks if it provides support functions that "fit" user needs**.

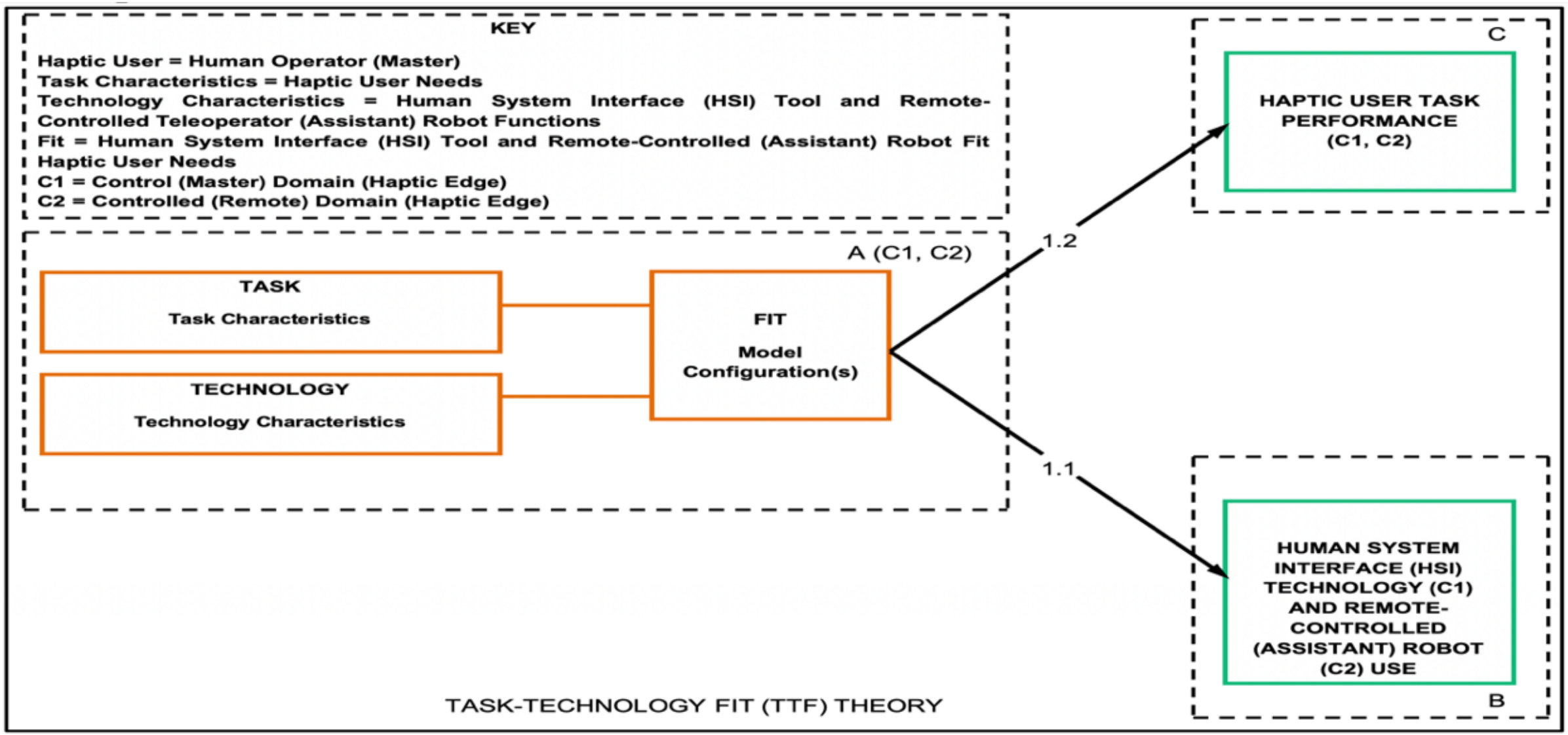
4) TTF & TTF Model
Task-Technology Fit (TTF) Theory



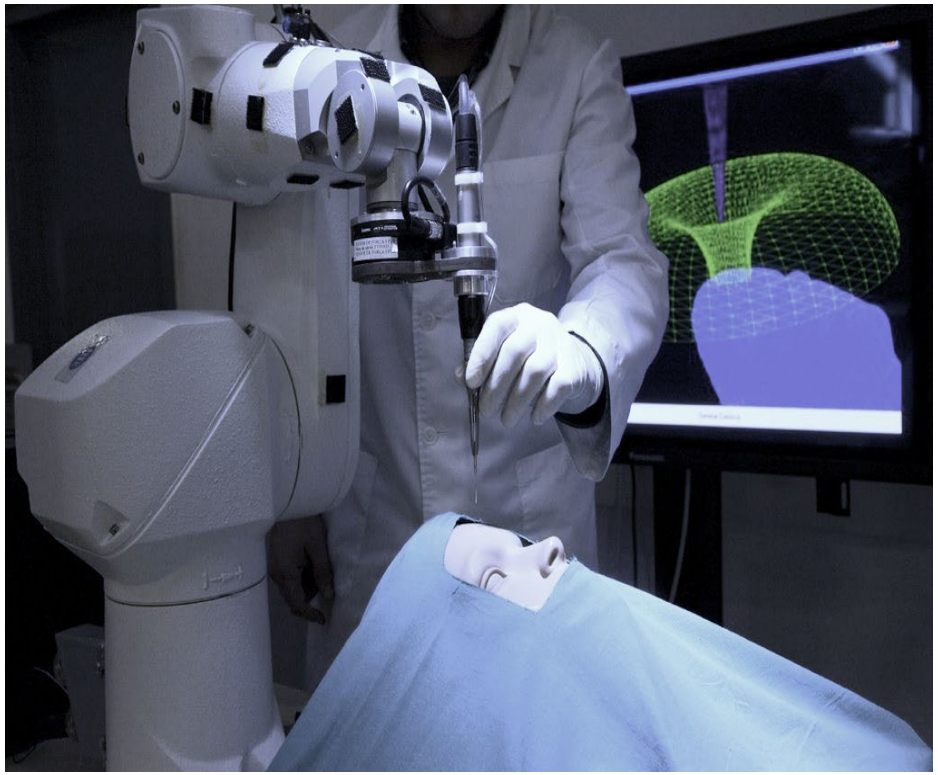
Source: Howard & Rose (Inf. & Mgmt., 2019). TTF was originally proposed by Goodhue & Thompson (MIS Q., 1995)

4) TTF & TTF Model

TTF model of 5G/Haptic Internet Remote Robotic Surgery

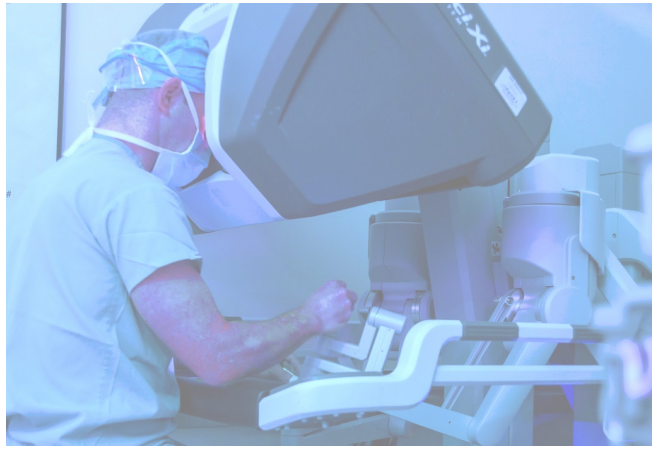


5) Methodology
Research approach and tools



- **Predictive (hypothetico-deductive) research design** to explain relationships between constructs in the conceptual TTF model.
- **Examine TTF and its use and user performance effects** on haptic-enabled technology use and task performance.
- Sets of **pre-validated, structured, questionnaire scale-item measures** adapted to the context of remote-robotic surgery.
- **Partial Least Squares – Structural Equation Modelling (PLS-SEM)** techniques, and **Polynomial Regression with Response Surface Methodology** to test potential non-linear effects of a Haptic-Enabled TTF on use and user performance.

5) Methodology
Task-Technology Fit (TTF) for Remote Robotic Surgery



TASK = Grasping, Palpation, and Incision

FIT

TECHNOLOGY = **Manipulator** (Hand Controller) and **Haptic-Device** (Remote Controller) + **Robotic Manipulators** (Grasper, Needle Driver/Forceps, Palpation (Probe), and End-Effector Tip (Cutter))

5) Methodology
Task construct (excerpt from the full paper)

TABLE 1. MEASUREMENT ITEMS FOR THE TASK (CHARACTERISTICS) CONSTRUCT

Variable	Scale Item		Source
Task Characteristics (TC A) [a]	TC 1 A	Control movement (motion) of remote assistant (surgical) robot.	[9], [10]
	TC 2 A	Feel and reproduce touch sensations when operating on remote patient.	
	TC 3 A	Feel and control grasping force for displacement manoeuvres performed on organs.	
	TC 4 A	Probe and detect lesions in organs through palpation manoeuvres.	
	TC 5 A	Perform incisions on (penetrate) soft tissue (blood vessels and nerves).	

[a] Measured on 7-point Likert scale: 1 = To an Extremely Small Extent, 2 = To a Very Small Extent, 3 = To a Small Extent, 4 = Somewhat, 5 = To a Large Extent, 6 = To a Very Large Extent, 7 = To an Extremely Large Extent

5) Methodology
Technology construct (excerpt from the full paper)

TABLE 2. MEASUREMENT ITEMS FOR THE TECHNOLOGY (CHARACTERISTICS) CONSTRUCT

Variable	Scale Item		Source
Technology Characteristics (TC B) [a]	TC 1 B	Control movement (motion) of remote assistant (surgical) robot.	[10]
	TC 2 B	Feel and reproduce touch sensations when operating on remote patient.	
	TC 3 B	Feel and control grasping force for displacement manoeuvres performed on organs.	
	TC 4 B	Probe and detect lesions in organs through palpation manoeuvres.	
	TC 5 B	Perform incisions on (penetrate) soft tissue (blood vessels and nerves).	

[a] Measured on 7-point Likert scale: 1 = To an Extremely Small Extent, 2 = To a Very Small Extent, 3 = To a Small Extent, 4 = Somewhat, 5 = To a Large Extent, 6 = To a Very Large Extent, 7 = To an Extremely Large Extent

5) Methodology
Use construct (excerpt from the full paper)

TABLE 3. MEASUREMENT ITEMS FOR USE CONSTRUCT

Variable	Scale Item		Frequency	Intensity	Dependence	Source
USE	U 1 [a]	Average number of times using Human System Interface (HSI) to remotely-control surgical robot (assistant) and perform surgical tasks.	✓			[14], [15], [16]
	U 2 [b]	Average time spent per day using Human System Interface (HSI) to remotely-control surgical robot (assistant) and perform surgical tasks.		✓		
	U 3 [c]	Overall dependence on using Human System Interface (HSI) to remotely-control surgical robot (assistant) and perform surgical tasks.			✓	

[a] Measured on 7-point Likert scale: 1 = Rarely, 2 = Less than Once a Month, 3 = Once a Month, 4 = A Few Times a Month, 5 = A Few Times a Week, 6 = About Once a Day, 7 = Several Times a Day

[b] Measured on 7-point Likert scale: 1 = Rarely, 2 = Less than ½ an Hour, 3 = ½ an Hour – 1 Hour, 4 = 1 – 2 Hours, 5 = 2 – 3 Hours, 6 = 3 – 4 Hours, 7 = More than 4 hours

[c] Measured on 7-point Likert scale: 1 = To an Extremely Small Extent, 2 = To a Very Small Extent, 3 = To a Small Extent, 4 = Somewhat, 5 = To a Large Extent, 6 = To a Very Large Extent, 7 = To an Extremely Large Extent

5) Methodology
User performance construct (excerpt from the full paper)

TABLE 4. MEASUREMENT ITEMS FOR USER PERFORMANCE CONSTRUCT

Variable	Scale Item		Effectiveness	Efficiency	Quality	Source
USER PERFORMANCE [a]	UP 1	Average number of times using Human System Interface (HSI) to remotely-control surgical robot (assistant) and perform surgical tasks.	✓			[17], [18], [19]
	UP 2	Average time spent per day using Human System Interface (HSI) to remotely-control surgical robot (assistant) and perform surgical tasks.		✓		
	UP 3	Overall dependence on using Human System Interface (HSI) to remotely-control surgical robot (assistant) and perform surgical tasks.			✓	

[a] Measured on 7-point Likert scale: 1 = To an Extremely Small Extent, 2 = To a Very Small Extent, 3 = To a Small Extent, 4 = Somewhat, 5 = To a Large Extent, 6 = To a Very Large Extent, 7 = To an Extremely Large Extent

6) Contributions and Future Work

Scientific contributions

1. Proposed and developed a **conceptual TTF model in the empirical context of remote-robotic surgery**, thereby providing a QoE-QoT-centric perspective of a 5G network and haptic-enabled Internet for real-time immersive remote surgical task performance.

2. This paper's results can **inform design guidelines** on how observed differential TTF in functional haptic technological support levels can **explain human haptic technology-enabled user task performance**.

Future work

Collect and analyse data from practising robotic surgeons to:

1. Initially **test and validate the TTF model** for this 5G network-enabled haptic IoS

2. Subsequently **understand real-time immersive surgical task performance from a QoE-QoT-centric perspective**.

7) Conclusions
Key takeaways

- Limitation of QoS / service requirements approach
- Evolution towards **Human-to-Machine/Robot (H2M/R) interaction** and paradigm shift from traditional and mobile Internet content delivery systems to skillset delivery systems, thereby realising a **haptic-enabled QoE and QoT centred IoS**.
- Potential extension of TTF model to other use cases and applications with similar characteristics (human in the loop, HITL)
- Importance of multi-/cross-/inter-/trans-disciplinary R&D for 5G and beyond 5G

7) Conclusions
Ultimately, it's about surgeons & patients not technology

"Success of robotic surgery lies solely in the skill of a surgeon"

"It's always the surgeon's hands, not the technology we use."

— *Nature*, Vol. 580, 23 April 2020, pp. S5-S7

Thank you

Contacts:

maradona.gatara@wits.ac.za || mjumo.mzyece@wits.ac.za || sijo@avantconiergeurol.com