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5G-enabled Health Systems: Solutions, Challenges and Future Research Trends

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A joint work in collaboration with National Health Center, National Telemedicine Center, National Engineering Laboratory for Internet Medical Systems and Applications, the first affiliated hospital of Zhengzhou University, Federal Univers of Piauí, Instituto de Telecomunicações and Waseda University.

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Atlanta, Georgia, USA

- **Revenue-driven investments**
  - More people, more potential revenues, more investments
  - Less people, less revenues, less investments

- **Result?**

Day and night of Zhengzhou City

Photos from the Internet

Photos from the Internet

More and more young middle-aged people moves to big cities

The elderly, ill and disabled people are left behind in remote villages

- **Digital gap between big cities and remote villages**
  - With the development of science and technology, most people moves to big cities for better opportunities
  - The people left behind in remote villages are elderly, ill and disabled
- **The inferior medical infrastructure and great treatment demand of remote area**
  - High-quality medical infrastructure is little in remote area due to less potential revenues
  - Elderly, ill and disabled people needs more medical treatments and cares

- **In-hospital case**
  - Human-dependent ward-rounds, care, and vital sign monitoring
  - Medical records cannot be timely shared among departments and hospitals
  - Telephone-call-based ambulance and emergency rescue
  - … …

How to deal with these problems?
ICT-assisted remote health

- **Weakness points of existing ICT-assisted remote health technology**
  - Less connected devices (e.g., in-home health needs vast connected vital signs' monitoring devices)
  - Slower transmission speed (e.g., remote diagnosis requires high-speed and high-definition medical image transmission)
  - Higher latency and inferior reliable communication (e.g., remote surgery needs nearly real-time latency and ultra-reliable connection)
  - **5G is a good solution for these weakness points!**

5G wireless connection
plus
Extranet

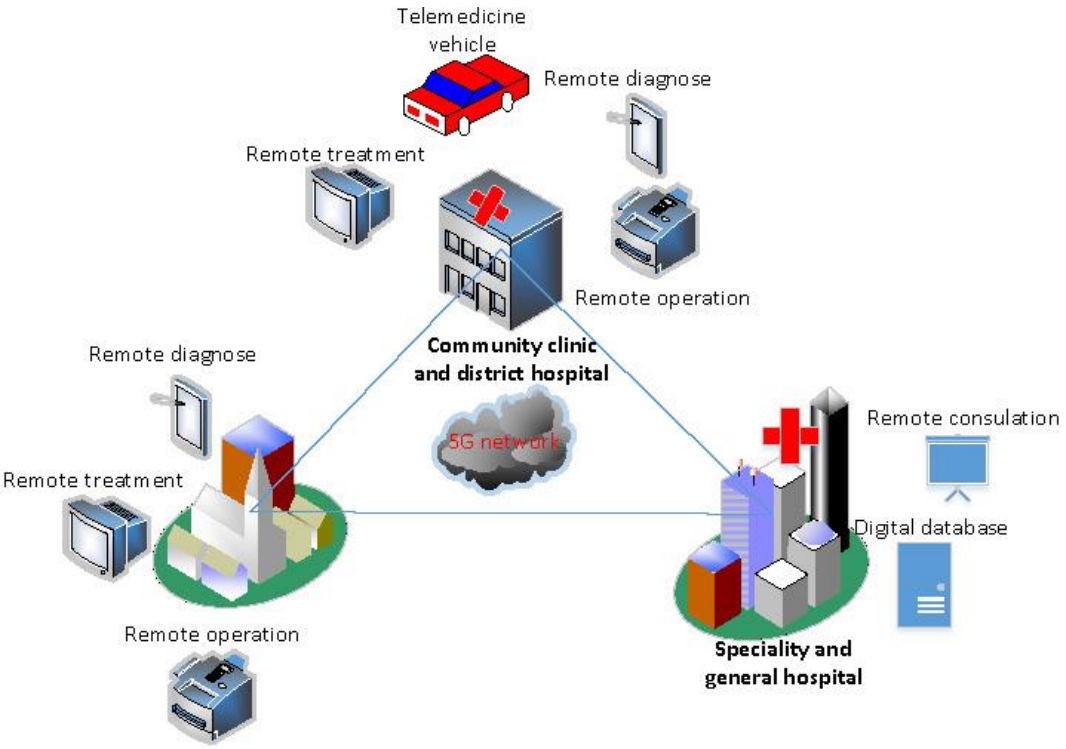
1 (Zhengzhou capital ci
+
18 (Prefecture city)
+
108 (Country)
+……
(Xinjiang is connected)


互联网医疗系统与应用国家工程实验室呼叫中心
每日实时动态
本月机器人服务业务分析
呼入/呼出30日分析
服务统计分析
本月热门机器人使用情况


今日会诊安排
2019年11月21日
09:25:35
序号 时间 申请医院 会诊科室 会诊专家 远程诊室
22 10:50 鹤壁市人民医院 肿瘤科 王伟 远程会诊室2
23 16:10 涌池县人民医院 磁共振科 张焱 中心会诊室2
24 16:20 鹤壁市人民医院 磁共振科 张焱 中心会诊室2
25 16:30 正阳县人民医院 磁共振科 张焱 中心会诊室2
26 16:30 巩义市人民医院 骨 科 黄宗强 远程会诊室1
27 16:40 正阳县人民医院 磁共振科 张焱 中心会诊室2

- **Three typical application scenarios of 5G**
  - Massive machine-type communications (mMTC)
  - Enhanced mobile broadband (EMBB)
  - Ultra-reliable low latency communications (URLLC)
- **Related 5G air interference technologies**
  - Massive multiple-input multi-output (MIMO)
  - Millimeter wave (mmWave)
  - Non-orthogonal multiple access (NOMA)
  - Wireless caching
  - … …
- **5G-enabled health systems**
  - 5G-enabled health systems for remote area
  - 5G-enabled in-hospital health systems

5G-enabled health systems for remote area



- Remote clinics are connected to big city's specialized and general hospitals
  - Remote diagnosis and treatmen
  - Automatic ambulance response and in-vehicle medical services

5G-enabled health systems for remote area

5G-enabled remote diagnosis demonstration

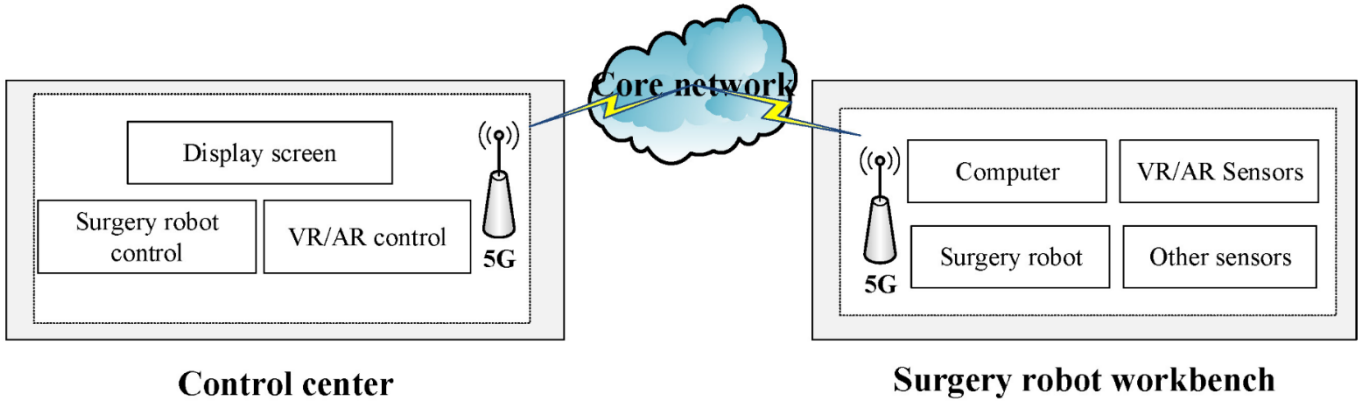
- Remote clinic of Huaidian village, Guangshan, Xinyang is connected to the first affiliated hospital of Zhengzhou university (FAHZZU)
  - High-quality medical service from FAHZZU
  - Reduced travel time and expense
- Main 5G test records from this demonstration
  - Uplink 100MB/s
  - Latency 7.6 ms

5G-enabled health systems for remote area

5G-enabled ambulance demonstration

- Main features
  - First-aider, ambulance, command center, remote clinic and the specialist and general hospitals are connected via 5G networks
  - In-vehicle remote diagnosis and treatment
  - Shared medical records, vital signs
  - Or even, remote in-vehicle surgery
- It can be also used for rescue and disaster relief

5G-enabled health systems for remote area



5G-enabled remote surgery

- Main points
  - Greatly relies on URLLC and eMBB
  - Virtual reality and artificial reality (VR/AR) technology-based 3D medical image processing
  - …
- We did not demonstrate the 5G-enabled remote surgery due to patient's potential risk

5G-enabled in-hospital health systems

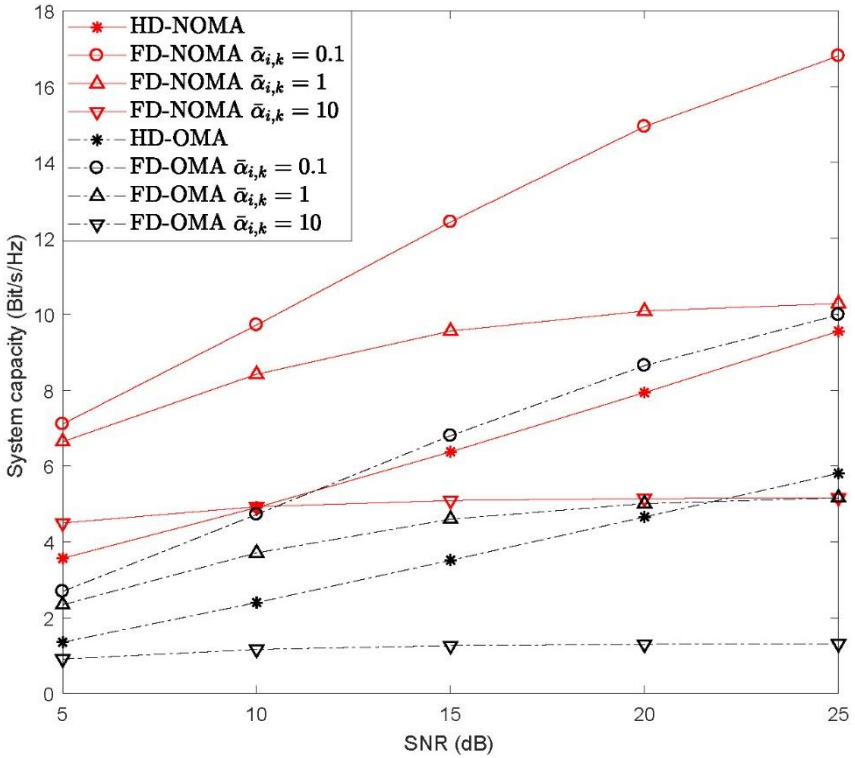
5G-enabled smart monitoring

- Main features
  - Vital-sign monitoring devices, intravenous injector, medical office, nurse station, etc., are connected together via 5G networks
  - Information sharing among the ward, nurse station and medical doctor office
  - Emergency pre-estimate and dispose

- **Challenging issues**
  - Trade-off between ultra-reliable and low-latency communications
    - Generally, more reliable transmission needs higher latency, and lower latency results in inferior reliable transmission (e.g., hybrid automatic repeat request (HARQ) retransmission can enhance the transmission reliability, but will bring in higher latency; short package transmission yields lower latency and less reliable transmission)
    - Redesigning the whole network from both core network and wireless section will be needed (e.g., network slicing, information centric networking (ICN))

- **Challenging issues**
  - Ethics of 5G-enabled health systems
    - Isaac Asimov's "Three Laws of Robotics"
    - when faced with a potential traffic accident, should the automatically drive ambulance hit the pedestrian or avoid it even through it might cause some serious injury to its passengers?
    - If intelligent enough, shall we treat the robot as machine or human?

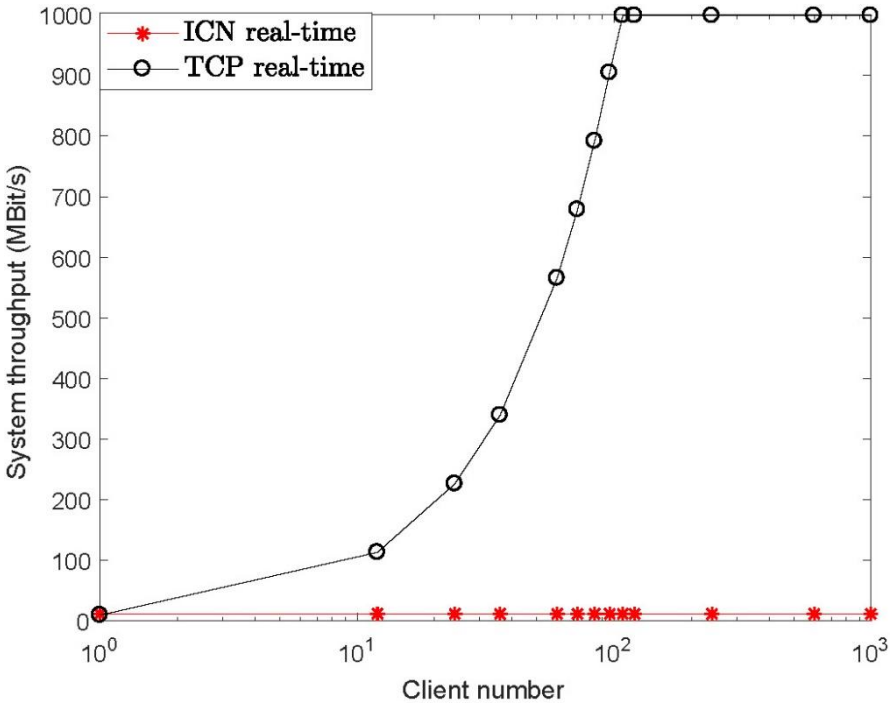
• Future research trends



System capacity comparison between HD-OMA, HD-NOMA, FD-OMA, and FD-NOMA

- Simulation settings
  - Normalized channel noise power
  - Allocated NOMA power [4, 2, 1]
  - Allocated orthogonal multiple access power 3.5
- Main findings here
  - Full duplex (FD) and NOMA always has better capacity performance compared to the half duplex (HD) and OMA
  - With signal to noise ratio (SNR) increasing, the merits of FD-NOMA is reduced due to self-interferences
- eMBB and URLLC are not solved yet by current 5G technology

• Future research trends



System throughput comparison between ICN-assisted edge computing and conventional scheme

- Simulation settings
  - per subscriber's transmission rate 10 MB/s
  - Increase the subscriber number
- Main findings here
  - ICN-based system has lower capacity performance, because it can obtain the required contents from neighboring subscriber's caches
- Potential sub-network congestion, optimal routing and algorithm, etc., are future topics

• Future research trends

- VR/AR-based medical image processing
  - How to detect the unexperienced targets
  - Large volume data and inferior processing ability
  - More effective processing algorithms and devices
  - … …

- # ACKNOWLEDGMENT

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Thank you