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# 5G Based Machine Remote Operation Development Utilizing Digital Twin

**Keywords:** 5G, remote operation, models, control

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**Extended abstract.** Remote mobile machinery operations require reliable and flexible communication. 5G networks provide ultra-reliable and low latency wireless communications upon which remote operations, real-time control and data acquisition can be implemented. In this paper we present a demonstration system for remote machinery control with 5G radio and Hardware-in-the-Loop development system (Figures 1 and 2).

Nokia's 5G proof-of-concept (PoC) radio is utilised in the demonstration. It consists of base transceiver station (BTS) and user equipment (UE) units forming the actual wireless radio link fulfilling the 5G requirements. This first evolution concept of 5G radios optimises the system communication paths and exploits the massive MIMO beamforming. The radio part is run at 3.95 GHz center frequency with 200 MHz bandwidth enabling as low as 1 ms delay in the link and increased capacity up to several Gbps compared to present LTE.

Actual machine control systems are connected to a dynamic simulation system for Hardware-in-the-Loop development. The test system is based on a real embedded machine control system relying on CAN-bus. Remote control has been implemented by bridging the complete CAN traffic over TCP/IP and the 5G radio. For haptic control, an additional HMI controller was added to control 3 degrees-of-freedom of the machine.

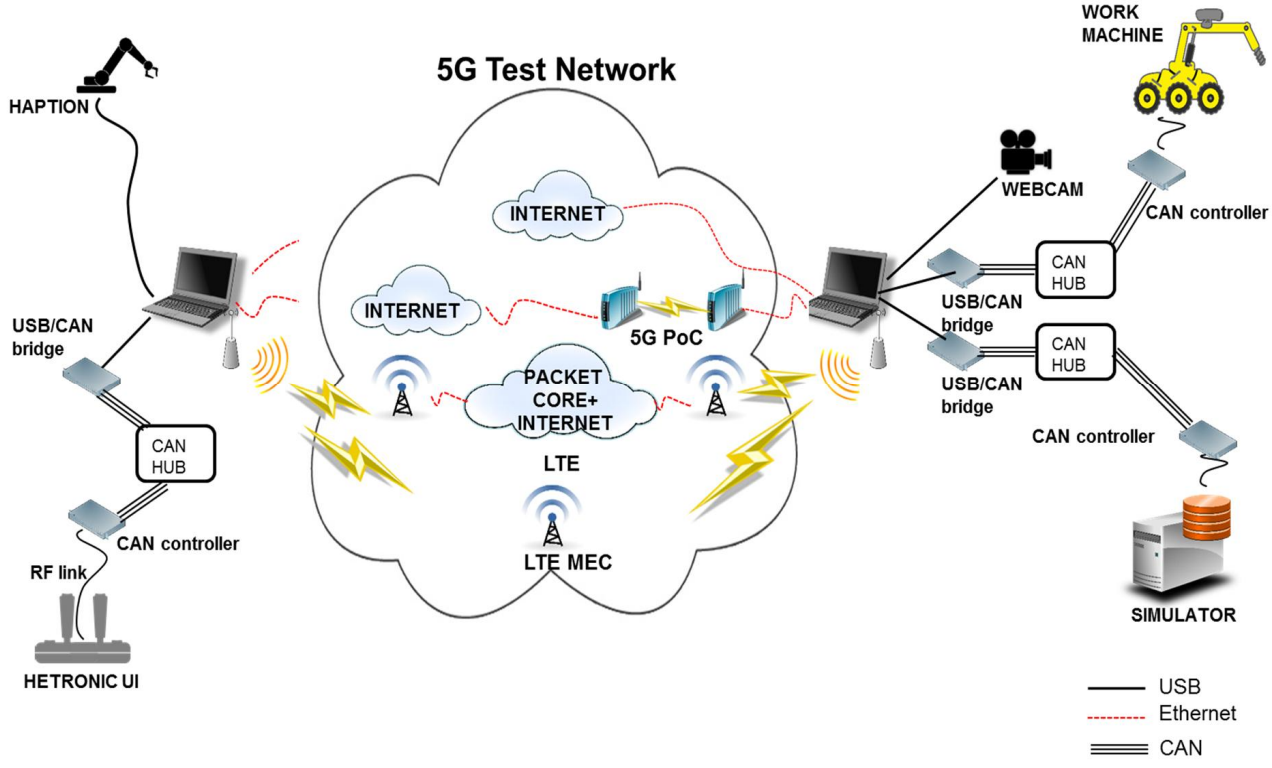


Figure 1. Remote operation of mobile machinery over the 5G networks and the internet..

Figure 2. 5G Proof-of-Concept radio.

Figure 3. Remote control station with haptic control.

Figure 4. Hardware-in-the-Loop simulator in the remote site.