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The Potential of Wireless 5G in Forestry Robotics

L-F Pau [1,2,3*]

[1]Copenhagen Business School, Denmark

[2]Erasmus University, Netherlands

[3]Upgötva AB, Sweden

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*Corresponding author: L-F Pau. Copenhagen Business School, Denmark; Erasmus University, Netherlands; Upgötva AB, Sweden,
Email: lpau@nypost.dk

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Introduction

At a time where telecommunications regulators embark on policies for deployment of the standardized 5th wireless mobile communications technology, the agricultural and forestry sectors don't pay much attention, farmers thinking at best about new smartphones and the usual specific information services they have got accustomed to. If indeed these policies, in their licensing conditions applying to wireless operators, mandate total coverage of exploitable farmlands and forests, there are huge consequences for future farming and forestry harvesting technologies. This is because the 5G technical specifications, technologies and standards allow for diverse and extreme requirements [1-4]. This includes near-zero-time latency, which is required for remote controlled robotics, as well as machine-to-machine data flows compatible with process control for moving objects (Table 1). It also includes the requirement that 5G must be able to combine multiple radio technologies, including Wi-Fi, into a single managed system. Finally, the 5G architecture is programmable to enable a diversity of new services.

Table 1: Key 5G performance figures.

Peak data rate	Downlink:20 Gbit/s, Uplink: 10 Gbit/s
User plane Latency, single user	4ms for eMBB, 1ms for URLLC
Control plane latency (idle to active)	10-20ms
Spectrum efficiency	Downlink 30 bit/s/Hz, Uplink: 15 bit/s/Hz
Area traffic capacity	10 Mbit/s/m^2
Connection density	1 M devices/km^2
Mobility	500 km/h in rural eMBB
User experienced data rate	100 Mbit/s, up to 1GHz in frequency bands above 6 GHz

For a while now, "precision farming" [5-8] has been used as a marketing concept by satellite positioning vendors, whereby global navigation satellite system (GNSS) receivers, combined with predictive analytical software , and positional accuracy enhancements , would allow farmers to: identify zones of variability within their fields ,use driverless tractors, increase seed density, control the movements of harvesters, planters, and sprayers. This trend had not spilled over onto forestry because of the canopy cover and the rough terrains, and the lack of customized approaches. And obviously, both for farming and forestry, "precision farming" equipment costs were so far often considered a limiting factor and treated as add-on's to existing machinery. Still, more difficult operating environments, scarcity of skilled workers and use of valuable crops, drive the search for high tech solutions. Because higher spectral bands will also be used in 5G , the geographical density of base stations (so called 5G Distributed Units and Central Units) will have to go up , to cope with propagation range and obstacle densities; in urban environments, small cells must be placed about every 300 m apart . For the USA alone, about 769 000 additional small-cell antenna sites will be needed by 2026 according to operator AT&T on top of the existing 349 344 sites (according to CTIA). While exploitable forests in general had in the past at best only bad 3G and 4G coverage by base stations with 30 km range or more adequate antenna modifications [9], it is to be expected that the 5G licensing conditions by public operators on coverage in exploitable forests will not be much better, except that 5 G base stations along access / traversing public roads will have to be less spaced , vastly enhancing signal conditions in lateral areas. But 5G also opens up for a distributed usage model, where other stakeholders than public operators shall be allowed to run private 5 G networks, as an extension to Wi-Fi hotspots.

The 5G Opportunity Combined with GNSS in Forestry

The main opportunity is therefore achieved by letting smaller 5G cells and interconnect devices be acquired and operated by forest owners, and embedded into forestry machinery, breaking the too long latencies of previously considered wireless communications technologies, and breaking as well to a large extent the radio propagation limitations by operating locally where harvesting is timely. Indeed, with almost zero latencies, a swarm of harvesters, loggers and transporters, could in a coordinated way harvest parcels under the supervision of very little personnel. This is called "swarm operations". Just to visualize this last concept, consider the following scenario. In a commercially exploited forest, with a specific exploitation plan, homogeneous parcels are harvested, using a combination/swarm of 2-3 harvesters, 1-2 thinners, and 2 forwarders. The harvesters are equipped with range finders allowing them, in addition to GNSS directional data [10], to move into the best positions for each trunk. The machinery units are operated simultaneously from initial positions determined by GNSS. The assignment and sequencing of tasks as well as locations is then determined by software, using a terrain model, machine characteristics, and eventually canopy information. The human operator launches the coordinated operations from a truck, carrying a 5G small base station, at a range of less than 500 m, and can override actions. The thinners, harvesters and forwarders are in real-time synchronized by 5G communications.

This has become realistic because it has been shown recently that directional guidance information for the collaborating machines is good enough for harvesters, even under dense forest environments, using autonomous satellite based global positioning systems, associated to short-distance ranging (laser based) [10]. It was also shown that such robotic forestry operations provide real cost savings and biomass yield gains [10]. In this context, low latency local 5G communications between harvesting machinery was the only missing link, assuming each machinery unit has power to move and can handle the mechanical tasks. Prior digital terrain data must still be acquired [11] and can be supplemented by eventually remote sensing or UAV surveying for biomass mapping [12].

By 5G connections between the machinery units, each in a known position, direction, elevation, speed and state, there is no need to use inaccurate machine vision or 3D stereo as advocated by some [13]. By allowing small distributed 5G units on the moving forestry machinery units, and thanks to the standardized features of 5G communication, the risk of interference is vastly minimized in the area of operation. As however interference may still affect GNSS signals [12], this 5G backup is a contributor to resilience in operations. Because the harvesting of a forest parcel does not require that many machine units (like the swarm of 8 units in the scenario), there is no need for procedures like RACH enabling millions of devices to access each other and the 5G network [14].

Another feature enabled by 5G communications in forest harvesting swarms, is to enhance work safety for human operators. First, dangerous tasks are largely taken over by harvesting and forwarding robots, and next collision avoidance is enabled by fast dynamic positioning information exchanged between the different units (like for drones [15,16]). So far, when communication links between machinery and human controller were too slow, and not resilient enough, safety was a limiting factor in forestry robotics. It was only in California that law allowed automated machines to operate without a driver as long as there was a safety remote switch to control throttle, clutch, and brakes, and speed was below 3 km/h.

Deployment

The above scenario relies on moving swarms normally not connected to public networks and Internet backbone. However, large forestry operators may choose to go beyond, subject to specific licenses being obtained. Actually, the laying of the interconnect optical fiber along some forest roads , or the installation of microwave links if terrain is hilly, could be the trigger for forestry companies to start to deploy forest harvesting robotics and other equipment allowing to enhance productivity and reduce a bit manpower costs. They may even accrue revenues from this infrastructure if made available also to public operators. With their long investment cycles in general, it should not be a major issue for forestry companies with large scale operations. The investment issue is however much harder for publicly owned and state forests, and for small forestry resources, let alone for the process of handling possible ducting permits.

Conclusion

Once the distributed 5G devices and small systems become more widely available, forward looking forestry equipment manufacturers and possibly some large private forest owners, may take up the opportunity to embark on robotic forestry operations. The enhanced services offered by newer GNSS systems [12] offer a compatible time window as well. The situation is completely different from 5G public networks for which the deployment may take maybe a decade, not the least because of the required fiber optic backbone expansion and the necessary hole digging.

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