Ostfalia
Hochschule für angewandte Wissenschaften

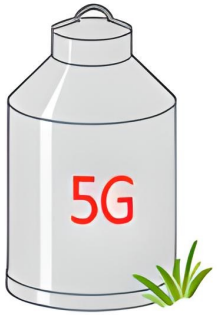
Nomadic Internet Connectivity under Forest Canopy

15.05.2024 – 28. VDE/ITG Fachtagung Mobilkommunikation

Martin Böhm and Diederich Wermser

Funded by 5G Smart Country (BMDV, FKZ: 45FGU117)

https://5g-smart-country.de



Smart Country

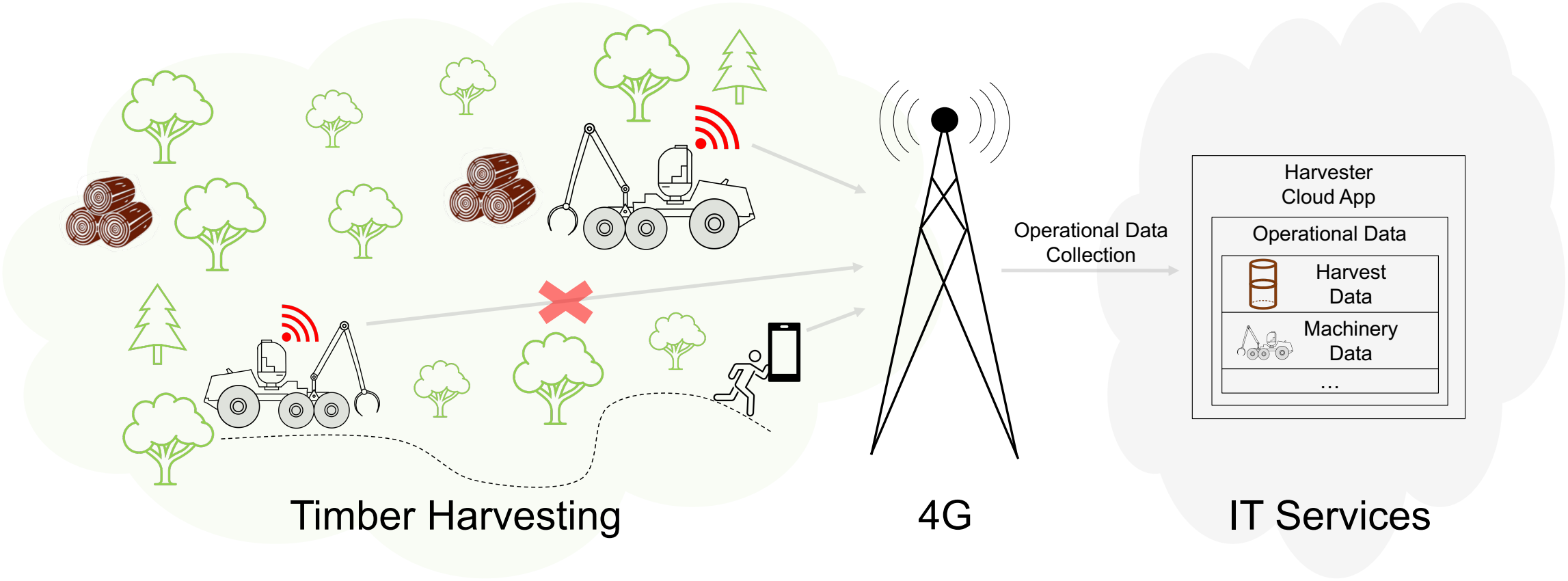
Ostfalia
Hochschule für angewandte Wissenschaften

Overview

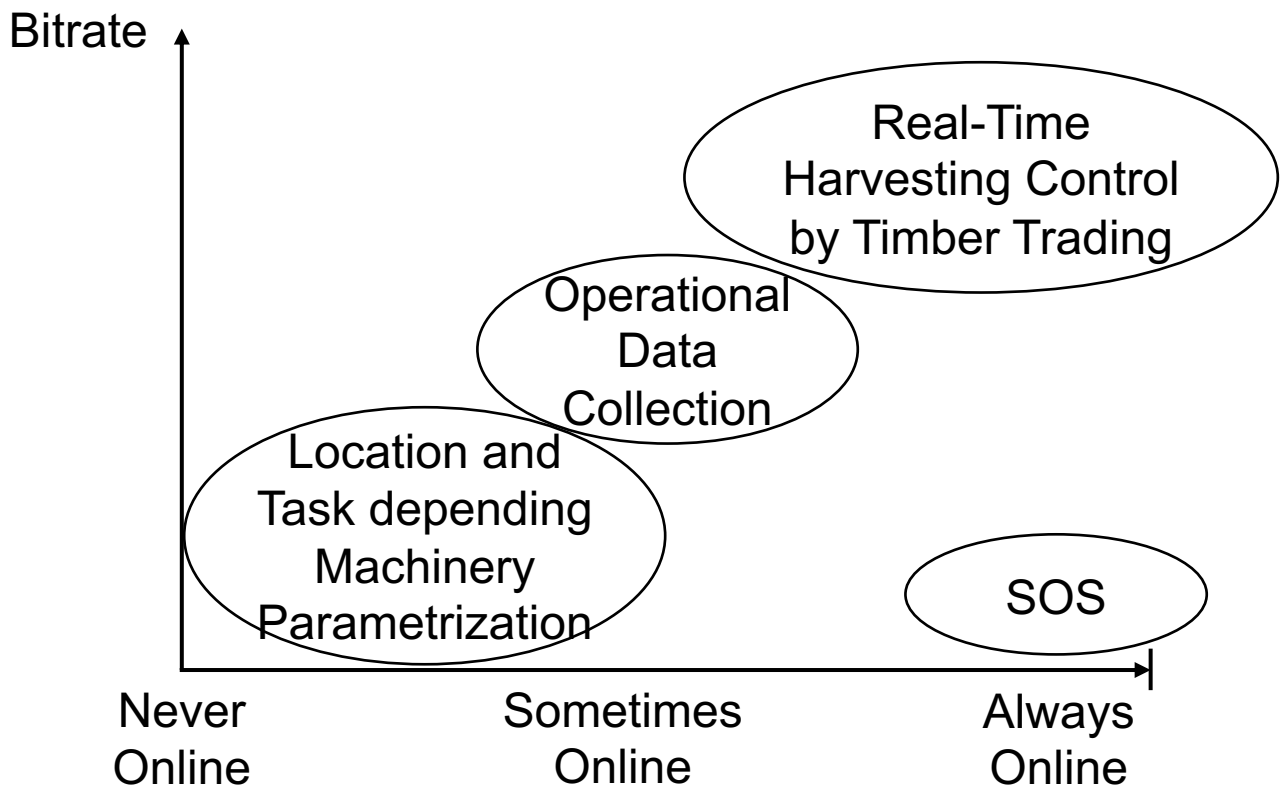
- Connected Timber Harvesting
- Alternatives for Mobile Internet Connectivity in Forests
- Above Forest Canopy
- Conclusion & Outlook

Ostfalia
Hochschule für angewandte Wissenschaften

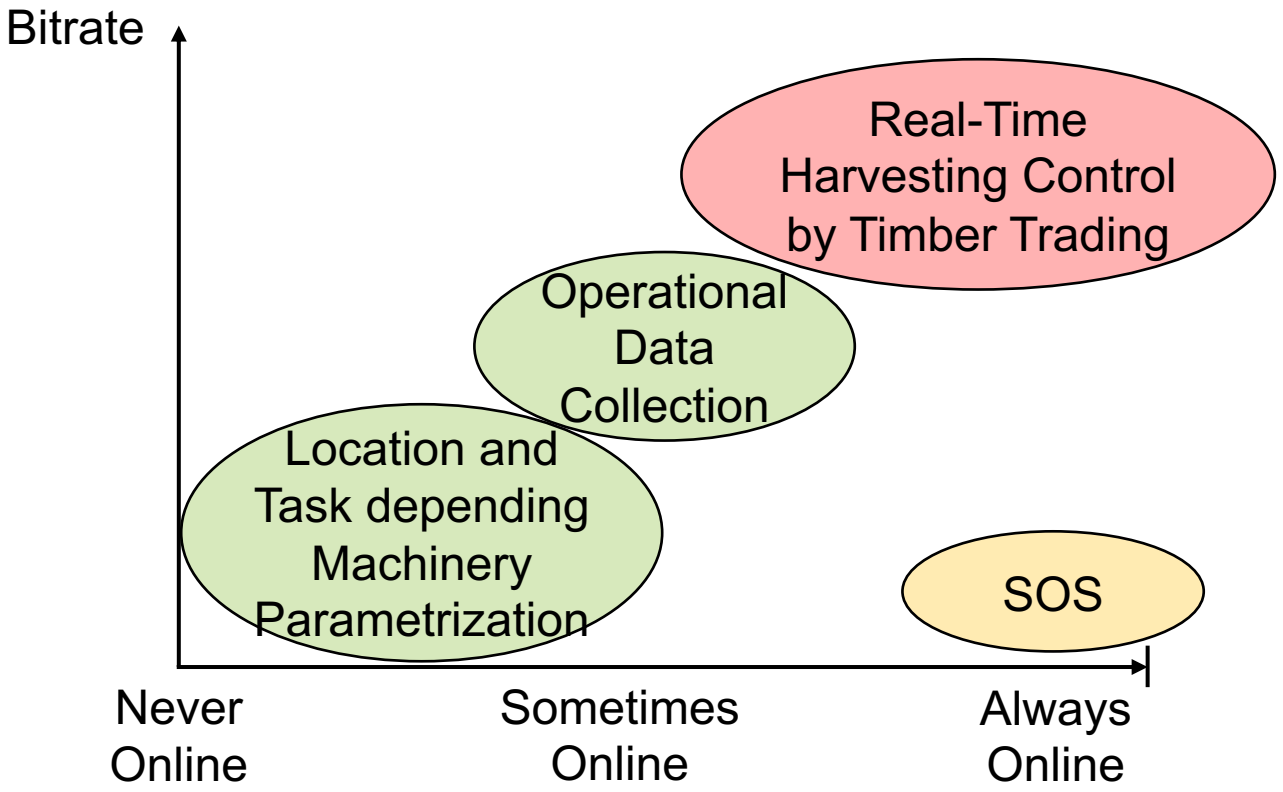
“Connected” Forestry Machinery – Today



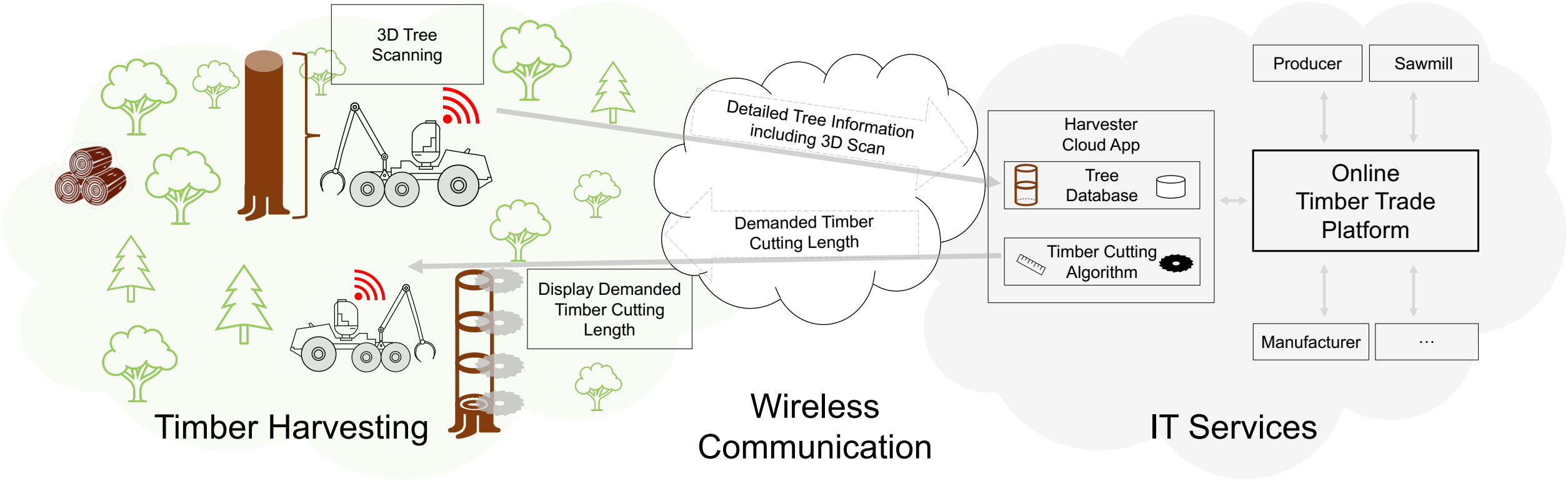
Connected Timber Harvesting – Some Applications



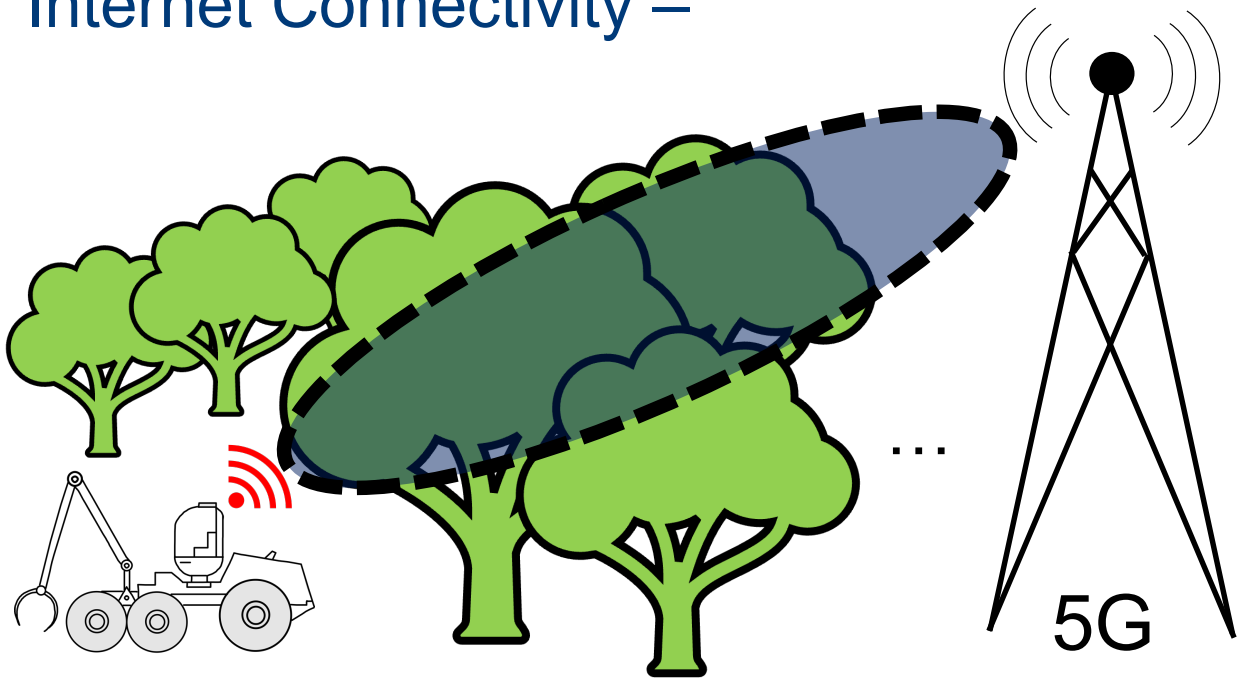
Connected Timber Harvesting – Some Applications

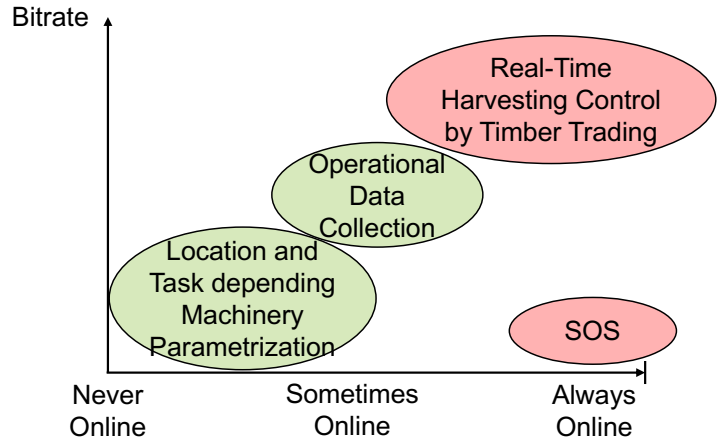


Connected Timber Harvesting – Real-Time Harvesting Control by Timber Trading



Alternatives for Mobile Internet Connectivity – Cellular Internet Connectivity –



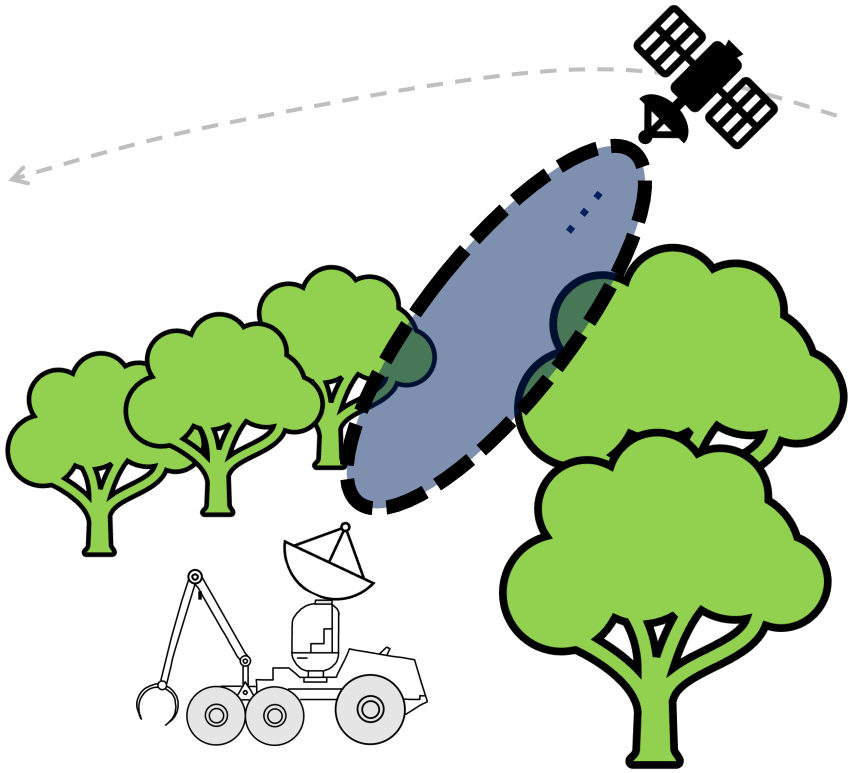


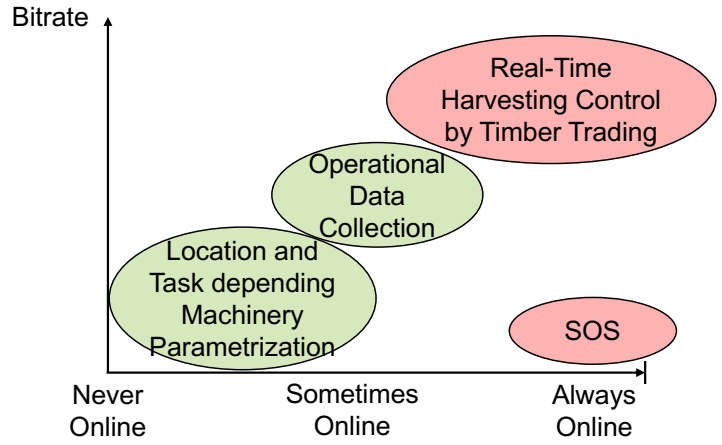
- Heavily obstructed Fresnel zone
- High attenuation caused by trees

→ Sufficient internet connectivity only available close to cellular base stations

Ostfalia
Hochschule für angewandte Wissenschaften

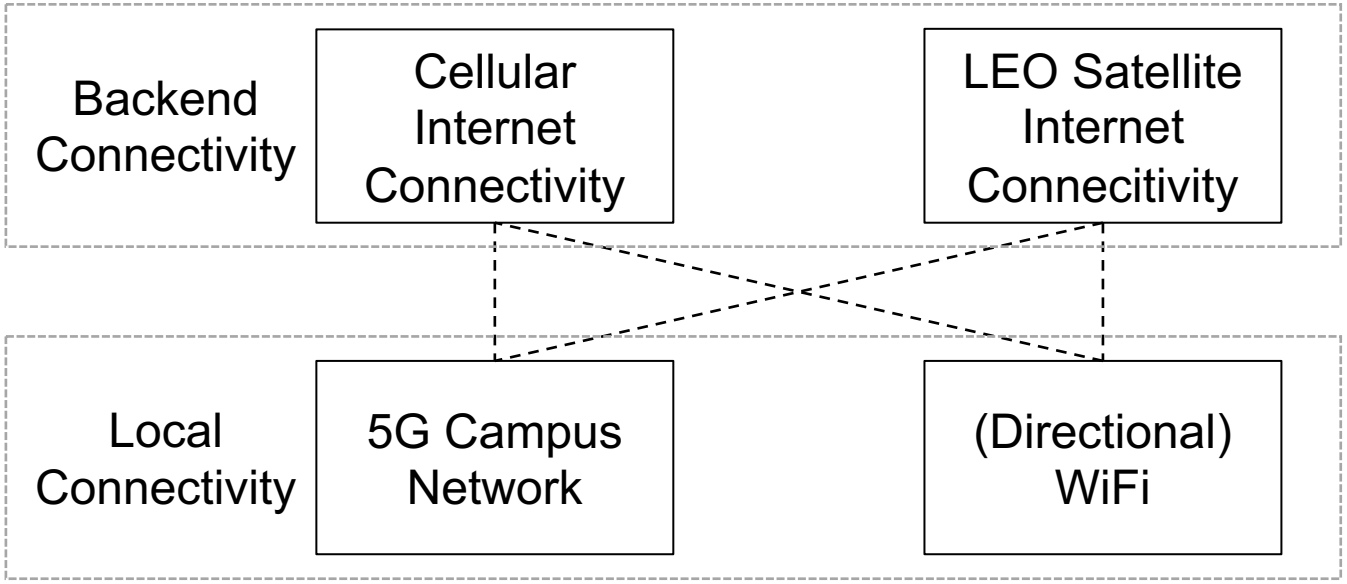
Alternatives for Mobile Internet Connectivity – LEO Satellite Internet Connectivity –

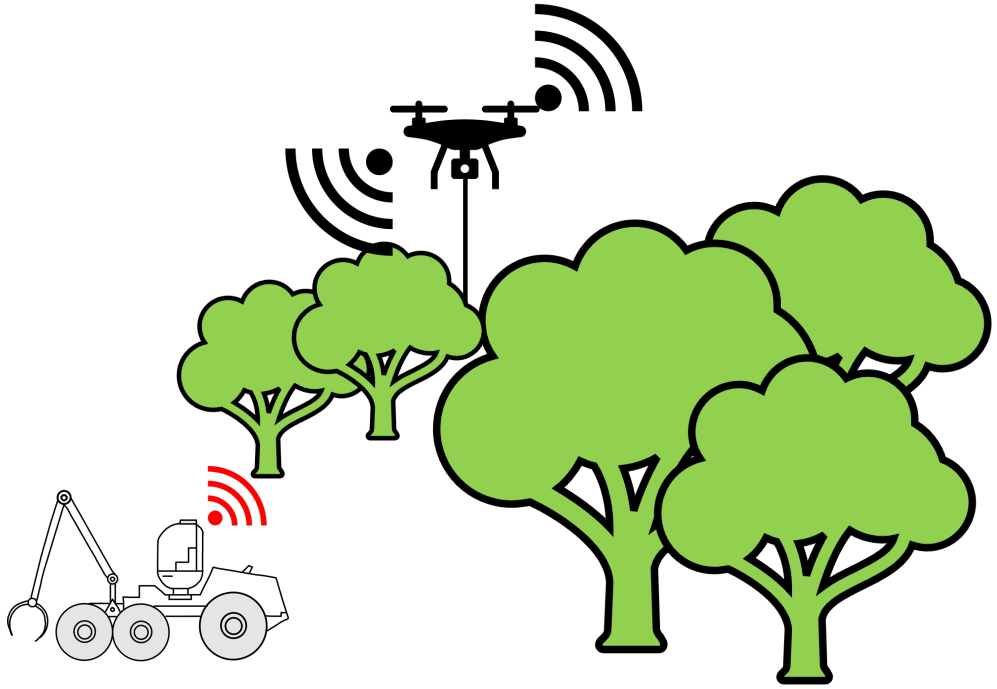




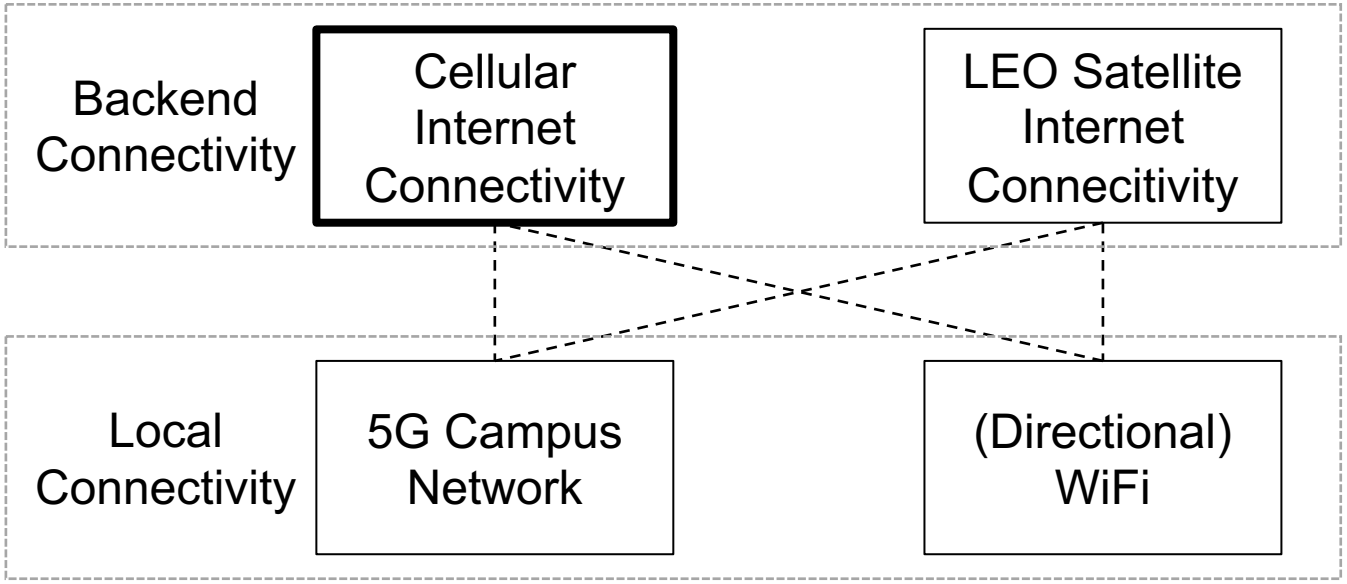
→ Intermitting internet connectivity

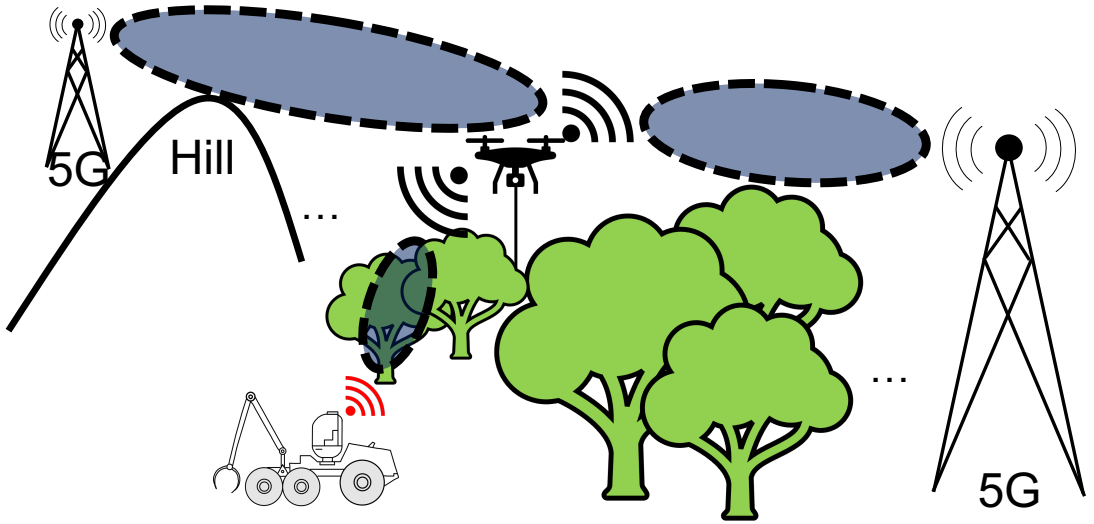
Alternatives for Mobile Internet Connectivity – Gateways above Forest Canopy –



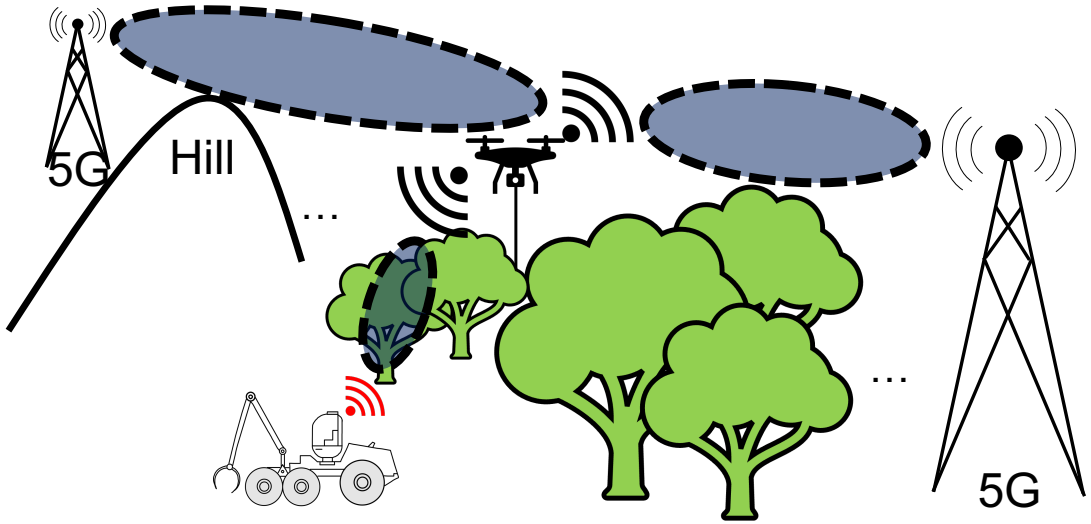


Alternatives for Mobile Internet Connectivity – Gateways above Forest Canopy –





Alternatives for Mobile Internet Connectivity – Gateways above Forest Canopy –



Evaluation of Cellular Backend Connectivity

- Example: Achievable mobile network bitrates at various heights (treetop heights ~25m)

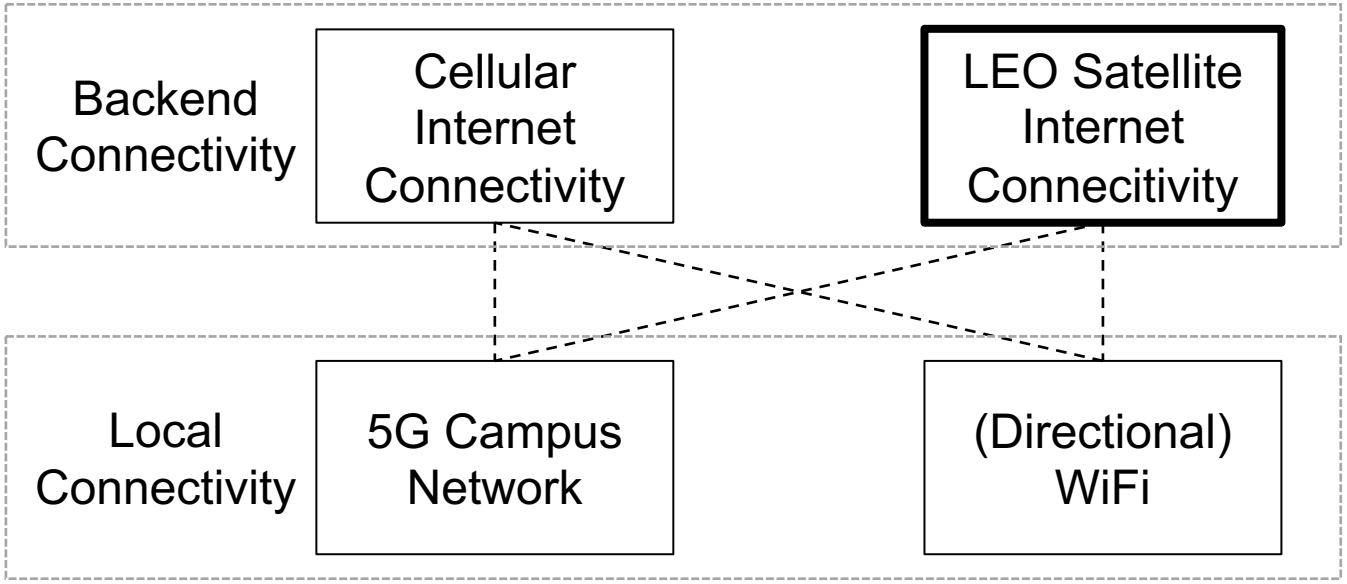
Height	Cell-ID-1 Freq.: 816/857 MHz Bandw.: 10 MHz (RSRP)	Cell-ID-2 Freq.: 816/857 MHz Bandw.: 10 MHz (RSRP)	Cell-ID-3 Freq.: 1720/1815 MHz Bandw.: 20 MHz (RSRP)	Visible Cells	Measured Downlink (Mbps)	Measured Uplink (Mbps)
2 m	-105 dBm	-105 dBm	-	6	5.56	0.65
5 m	-104 dBm	-110 dBm	-	9	6.09	3.09
10 m	-104 dBm	-109 dBm	-	10	6.64	3.22
15 m	-103 dBm	-110 dBm	-	13	7.12	3.95
20 m	-95 dBm	-104 dBm	-123 dBm	17	9.63	7.77
25 m	-91 dBm	-99 dBm	-117 dBm	18	13.15	14.48
30 m	-86 dBm	-92 dBm	-112 dBm	19	14.31	15.37
35 m	-84 dBm	-94 dBm	-111 dBm	20	12.55	14.68
40 m	-86 dBm	-93 dBm	-101 dBm	21	10.63	17.02
45 m	-91 dBm	-88 dBm	-96 dBm	23	89.55	45.05
60 m	-84 dBm	-83 dBm	-96 dBm	24	92.73	82.24

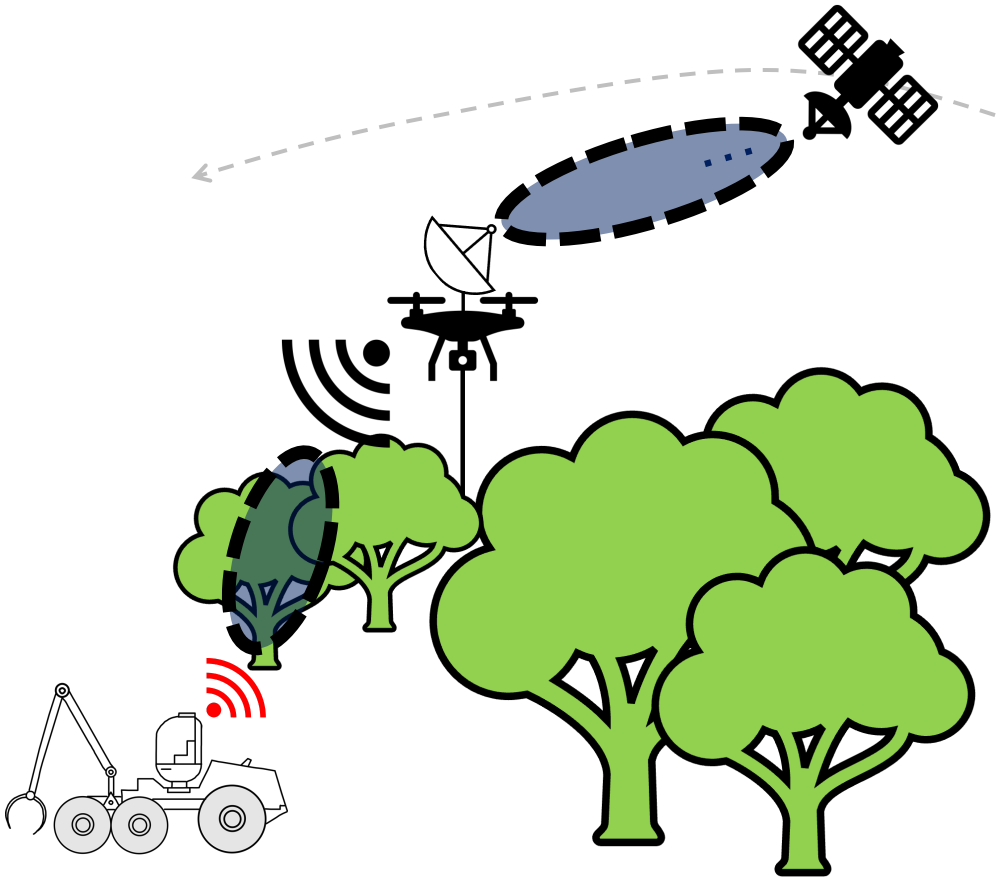
Evaluation of Cellular Backend Connectivity

- Example: Achievable mobile network bitrates at various heights (treetop heights ~25m)

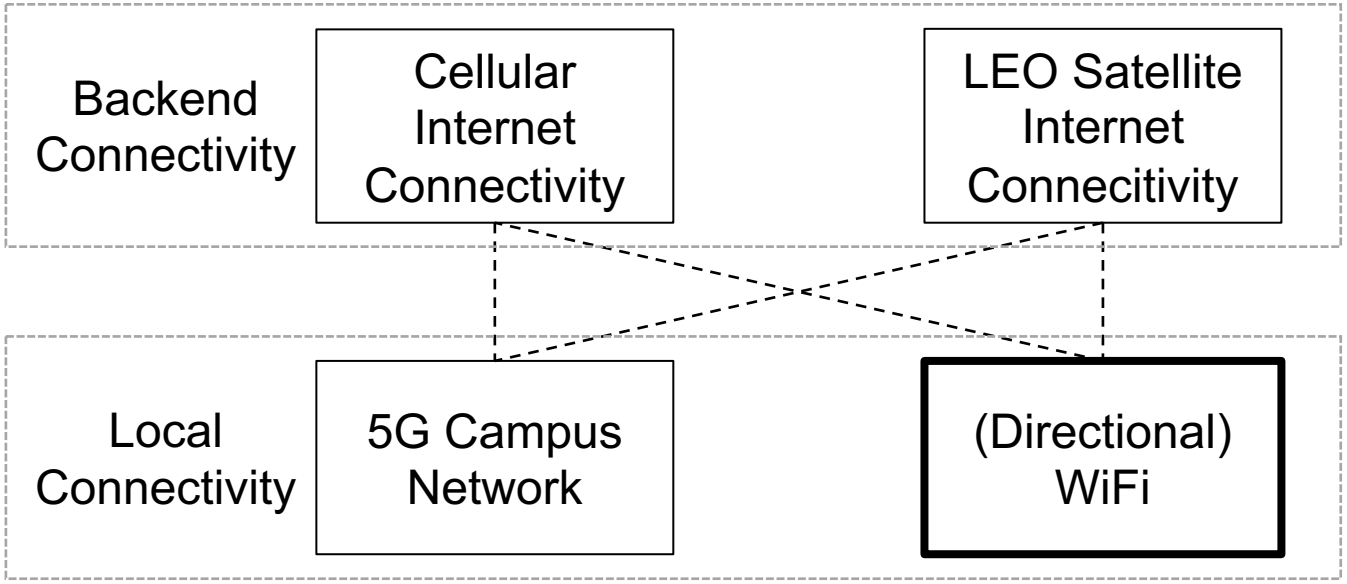
Height	Cell-ID-1 Freq.: 816/857 MHz Bandw.: 10 MHz (RSRP)	Cell-ID-2 Freq.: 816/857 MHz Bandw.: 10 MHz (RSRP)	Cell-ID-3 Freq.: 1720/1815 MHz Bandw.: 20 MHz (RSRP)	Visible Cells	Measured Downlink (Mbps)	Measured Uplink (Mbps)
2 m	-105 dBm	-105 dBm	-	6	5.56	0.65
5 m	-104 dBm	-110 dBm	-	9	6.09	3.09
10 m	-104 dBm	-109 dBm	-	10	6.64	3.22
15 m	-103 dBm	-110 dBm	-	13	7.12	3.95
20 m	-95 dBm	-104 dBm	-123 dBm	17	9.63	7.77
25 m	-91 dBm	-99 dBm	-117 dBm	18	13.15	14.48
30 m	-86 dBm	-92 dBm	-112 dBm	19	14.31	15.37
35 m	-84 dBm	-94 dBm	-111 dBm	20	12.55	14.68
40 m	-86 dBm	-93 dBm	-101 dBm	21	10.63	17.02
45 m	-91 dBm	-88 dBm	-96 dBm	23	89.55	45.05
60 m	-84 dBm	-83 dBm	-96 dBm	24	92.73	82.24

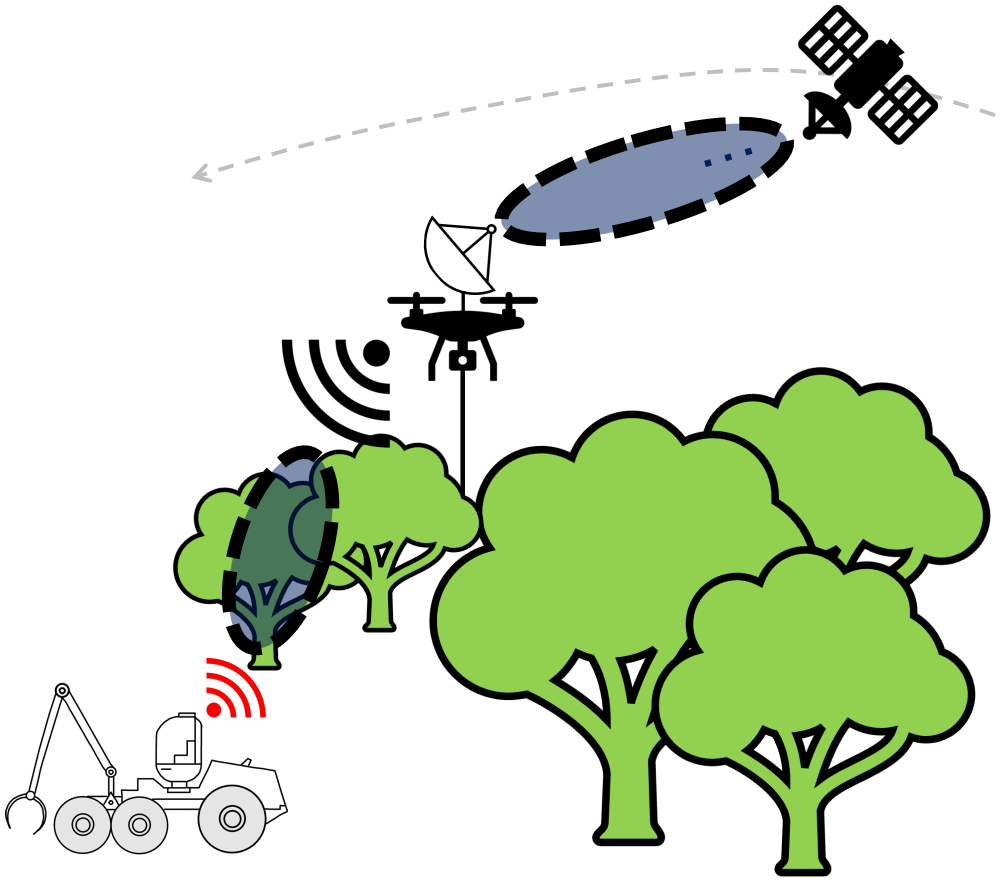
Alternatives for Mobile Internet Connectivity – Gateways above Forest Canopy –





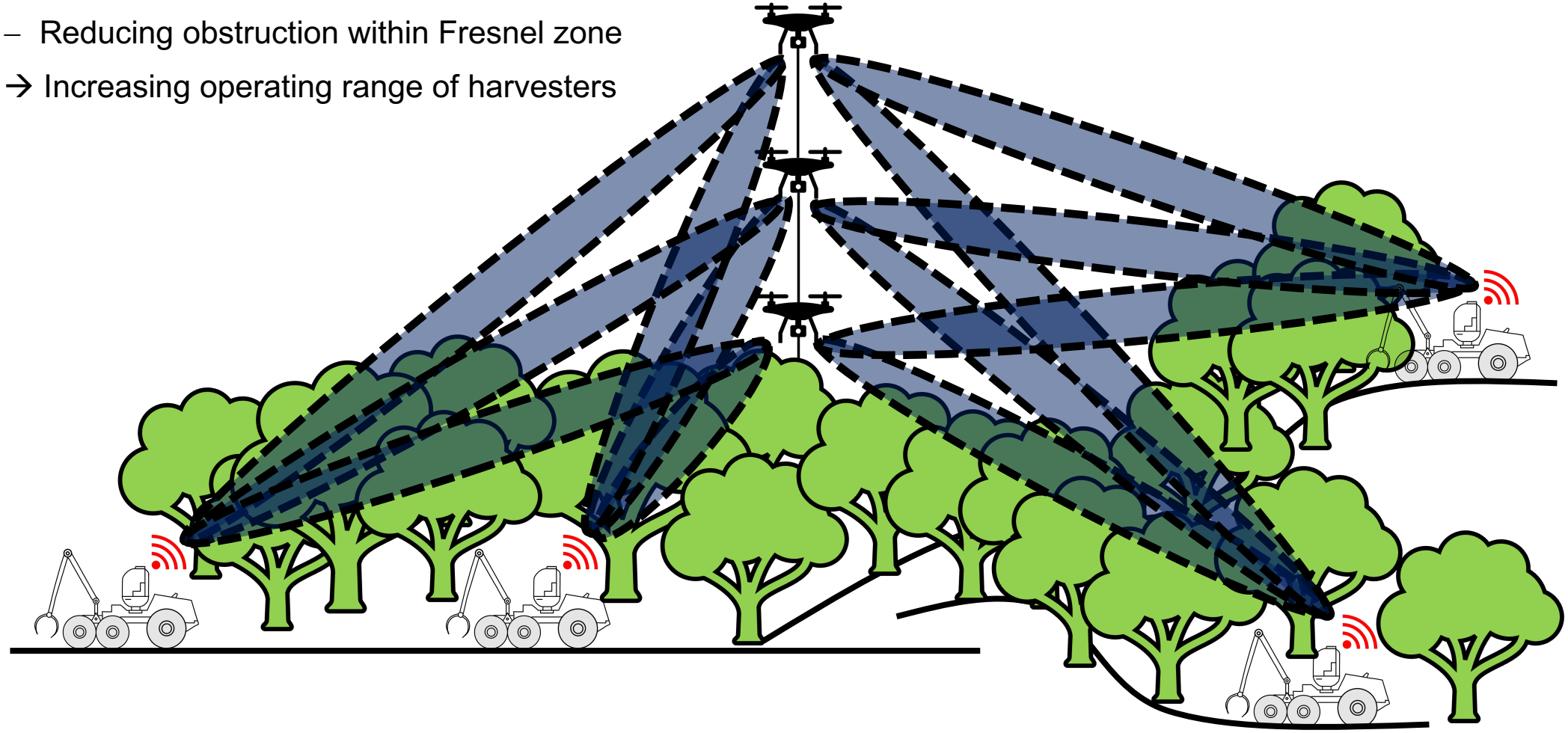
Alternatives for Mobile Internet Connectivity – Gateways above Forest Canopy –





Local Connectivity – Drone Height

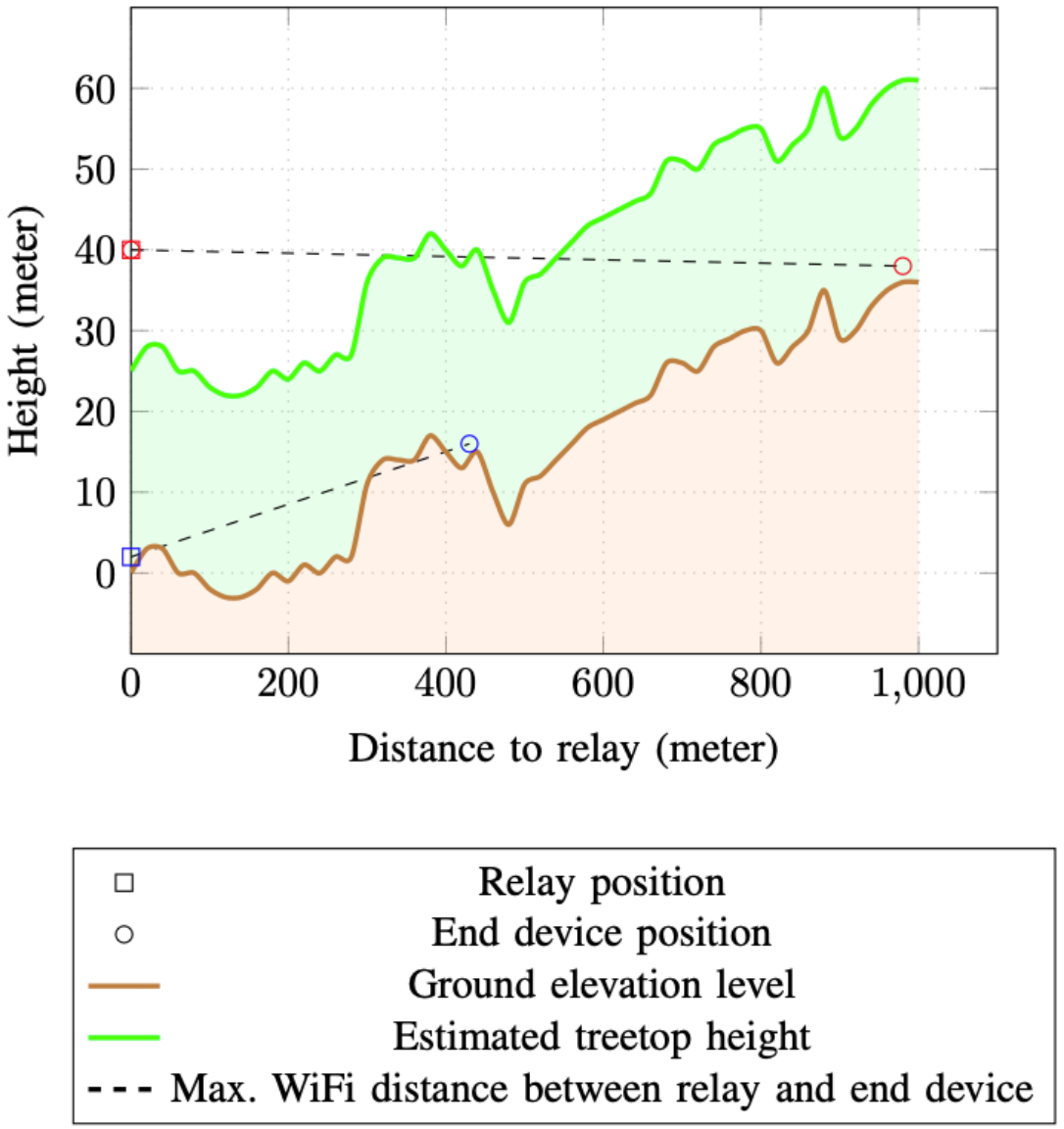
- Drone height improves local connectivity
  - Reducing obstruction within Fresnel zone
  - → Increasing operating range of harvesters



Ostfalia
Hochschule für angewandte Wissenschaften

Evaluation of Local Connectivity – Example WiFi Measurements –

- Forest 1 – Max distance in different heights
  - Max distance: stable bidirectional bandwidth ≥ 1 Mbps
    - 2m relay height: 430m distance
    - 40m relay height: 980m distance
- Forest 2 – Achievable bitrates at different heights (fixed distance)
  - 410m fixed distance, similar ground elevation level
    - 35m relay height: 1 Mbps achieved
    - 40m relay height: 23 Mbps achieved
- Achievable performance is strongly influenced by factors such as tree density, variations in elevations, vegetation, …



Ostfalia
Hochschule für angewandte Wissenschaften

Conclusion & Outlook

- Radio relays operating above forest canopy enable new IT applications for forestry machinery
- Experiences with tethered drones show their potential
- Drone height improves local connectivity and 5G backend bitrates

- Cost reductions and additional revenues of IT applications must justify additional costs and efforts
- LEO satellite antennas mounted on harvester (phased array Starlink antenna) will experimentally be evaluated
  - How is the online time distributed over time in relevant harvester operating scenarios? For which IT applications is this sufficient?
  - How can the phased array antenna be protected against rough mechanical conditions on the rooftop of harvesters?