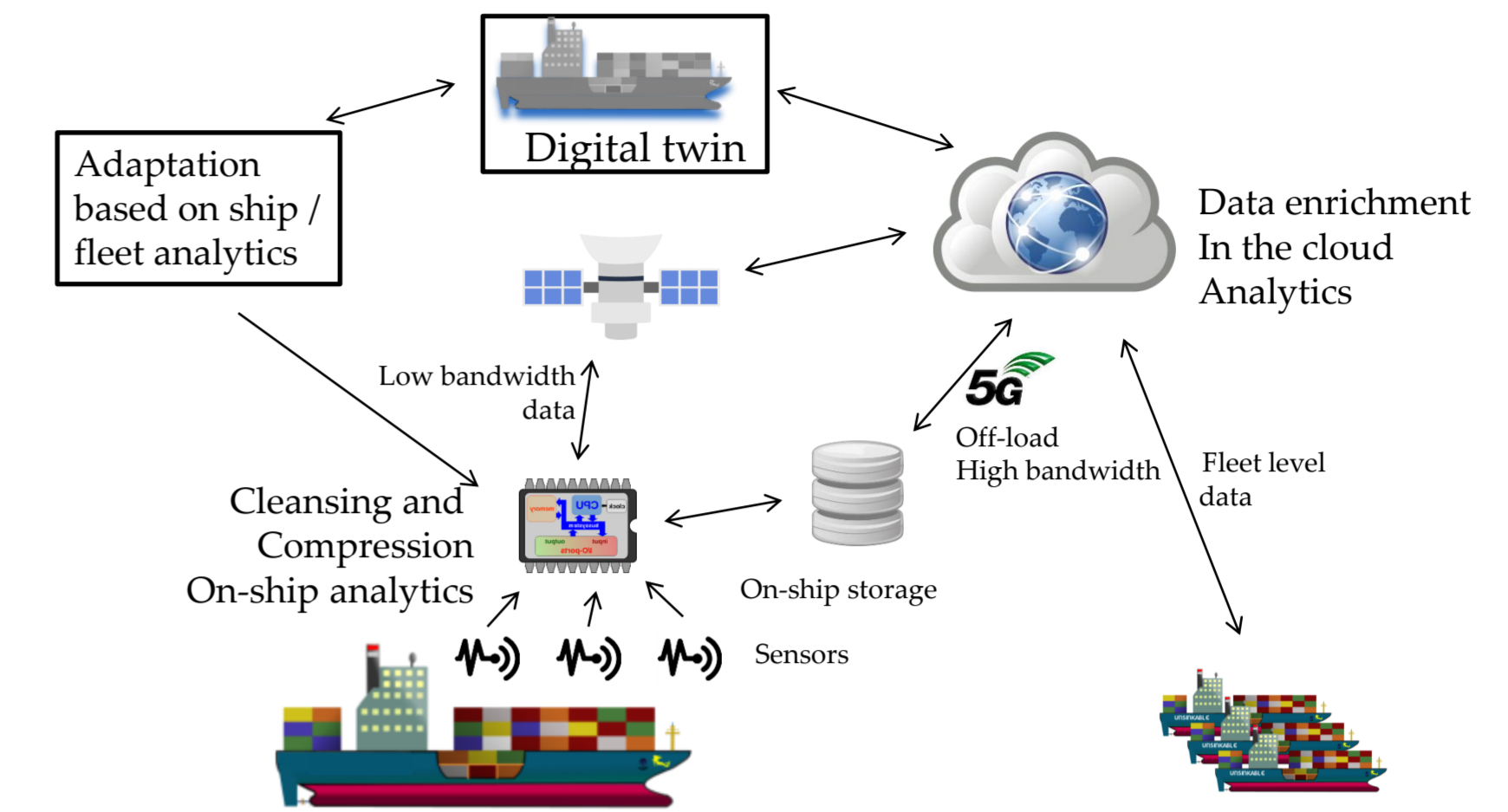


# IoT at Sea

## Autonomous Ships and Connectivity

- Autonomy in the shipping industry requires next level of situation awareness
- Autonomous ships need communication with land based stations
- Autonomous ships can be seen as IoT capable vessels
- Connectivity is required also on the high seas, where terrestrial networks have no coverage



## Frequency Spectrum and Connectivity Requirements

Band Number	Band	Frequency Range	Band Capacity @ SNR -10 dB	Propagation Modes	Coverage	Susceptibility
0	ELF	0.3-3 Hz	10 <sup>1</sup> bps			
1		3-30 Hz	10 <sup>2</sup> bps			
2		30-300 Hz	10 <sup>3</sup> bps			
3	ULF	300-3000 Hz	10 <sup>4</sup> bps			
4	VLF	3-30 kHz	10 <sup>5</sup> bps	groundwave, skywave	Up to 5000 nmi	Noise, skywave multipath
5	LF	30-300 kHz	10 <sup>6</sup> bps	groundwave, skywave	Up to 1000 nmi	Noise, skywave multipath
6	MF	300-3000 kHz	10 <sup>7</sup> bps	groundwave, skywave	Up to 1000 nmi	Noise, skywave multipath
7	HF	3-30 MHz	10 <sup>8</sup> bps	groundwave, skywave	Worldwide	Noise, ionospheric activity
8	VHF	30-300 MHz	10 <sup>9</sup> bps	Freespace	LOS	Terrain multipath
9	UHF	300-3000 MHz	10 <sup>10</sup> bps	Freespace	LOS	Terrain multipath
10	SHF	3-30 GHz	10 <sup>11</sup> bps	Freespace	LOS	Weather, terrain multipath
11	EHF	30-300 GHz	10 <sup>12</sup> bps	Freespace	Limited LOS	Weather, gaseous absorption
12		300-3000 GHz	10 <sup>13</sup> bps			

Use Case	Bandwidth Estimate	Reliability Requirement	Latency Requirement	Coverage requirement	Communication Type
Navigation / Position reporting	bit/s	medium	seconds	Worldwide	Ship to land
Navigation / Collision avoidance	kbit/s	high	seconds	Worldwide	Ship to ship
Navigation / Route optimization	kbit/s	medium	hours	Worldwide	Land to ship
Navigation / Video streams	Mbit/s	high	milliseconds	Coastal	Ship to land
Navigation / Remote control	kbit/s	high	milliseconds	Coastal	Land to ship
Automation / Predictive maintenance	Mbit/s	hours	medium	Harbor / coastal	Ship to land
Automation / Raw sensor data	Mbit/s	hours	medium	Coastal	Ship to land
Automation / Diagnostics analysis	bits/s	high	seconds	Worldwide	Ship to land
Operations	kbit/s	medium	minutes	Worldwide	Land to ship
Operations / Asset tracking	Mbit/s	medium	minutes	Harbor	Ship to land
Safety / Distress call	bits/s	high	seconds	Worldwide	Ship to land / Ship to ship
Entertainment / Live media	Mbit/s	low	minutes	Coastal	Land to ship
Entertainment / Social	kbit/s	low	minutes	Worldwide	Land to ship

## Measurements

- Measured RSSI on-board a cruising vessel in the Turku archipelago for several months
- Unusually cold winter during measurements (continuously well below -10 °C)
- Transmitter at Korpoström and repeater at Flatö
- Frequency: 428.5 MHz, Power level 5 W (peak rating), data rate 50-100 kbit/s
- Max distance between transmitter and vessel was 38 km

