Communication Infrastructures in Industrial Automation: The Case of 60 GHz MillimeterWave Communications

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Outline

• Motivations

• Characteristics of 60 GHz mmW communications

• Potentials of 60 GHz communications in automation

• Challenges

• Conclusions
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- **tight time and data rate requirements, long duty cycles**
  - fast data exchange between central controller-distributed I/O modules (≈ milliseconds)
  - real-time visualization or recording data transmission (≈ Gb/sec)
  - higher data rates ⇒ smaller duty cycle
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• lack of Gbps solutions with **strict real-time guarantees** [CMH10]
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Characteristics: 60GHz mmW communications

- 3-300GHz spectrum → mmW bands (\( \lambda \) ranges from 1-100mm)

Figure: Millimeter-wave spectrum, Source: [ZK11]
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- large amount of spectral bandwidth: **7GHz**

- achievable data rates $> 2$Gbps

Figure: Millimeter-wave spectrum, Source: [ZK11]
Characteristics: 60GHz mmW communications

Figure: Variation in Received Power with 32mW transmit power at 5.1GHz (left) and 60GHz (right), Source: [WAN97]

- do not penetrate most solid materials $\rightarrow$ extra spatial isolation
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- do not penetrate most solid materials → extra spatial isolation
- coverage is defined by the perimeter of the room
- frequency reuse is viable
- implicit security
Characteristics: 60GHz mmW communications

- Oxygen absorption

Figure: Working range and frequency reuse, Source: FCC OET Bulletin 70a
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- 98% of the transmitted energy is absorbed within first Km
- natural choice to avoid interference
- dense deployments of radio terminals operating on the same frequency

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Figure: Wafer-scale antenna: 64 elements in 8-12GHz (left) and 1024 elements in 50-75GHz (right), Source: [Moh06]

- (antenna dimension) $\propto \lambda$
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• MIMO $\rightarrow$ SDMA $\rightarrow$ (point to multipoint communication)
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- narrow beams

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- point-to-point mesh networks

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Figure: 60GHz applications in general

Weeraddana, et al. (KTH, ABB)
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- **reliability**
  - safety-related data transmission (e.g. emergency stop)
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- frequency decoupling
  - narrow beams
  - O₂ absorption
  - interference immunity

- spatial decoupling
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**sophisticated beamforming techniques**

exploit multipath diversity

beam steering mechanisms

seek for an LOS access point

**FEC**
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- ↑ directivity ⇒ ↓ angular separation of multipaths ⇒ ↓ DoF gain
  - presence of many obstacles → natural solution
  - omni directional antennas (recall: there is spacial decoupling)
  - switched-beam antennas, cylindrical/spherical array antennas

- $O^2$ absorption, solid walls ⇒ attenuation
  - higher transmission power
  - higher beamforming gains with multiple antennas
  - dense deployment of access points (AP) → maximize diversity
  - APs with multi-beam maneuvering capabilities

- ISI: equalization, OFDMA
  - baseband signal processing
    - analog domain signal processing
    - passive antenna elements, e.g., paraboloid/linear parasitic reflectors

- power requirements
  - analog domain signal processing
  - blend many technologies ⇒ new signalling protocols
  - video tracking with high resolution → unidirectional 60GHz communications
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Conclusions

• unlicensed operation – FREE !!

• Gbps data rates

• supports coexistence with old technologies

• inherent interference free operations, high frequency reuse, high densities

• small profile

• mature technology, e.g., CMOS

• reliability: links with “five nines” of availability if desired

• 60GHz: A PROMISING TECHNOLOGY → BLEND INTO EXISTING TECHNOLOGIES USED IN FACTORY/PROCESS AUTOMATION
Thank you
Survey on wireless sensor network technologies for industrial automation: The security and quality of service perspectives. 

[Moh06] F. Mohamadi. 
Build a phased array on a wafer to boost antenna performance. 

Investigating the effects of antenna directivity on wireless indoor communication at 60 ghz. 

An introduction to millimeter-wave mobile broadband systems. 