Edge Computing Benefits in Low-Latency IoT Applications

Michael Amista’

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Prof. Claudio Enrico Palazzi

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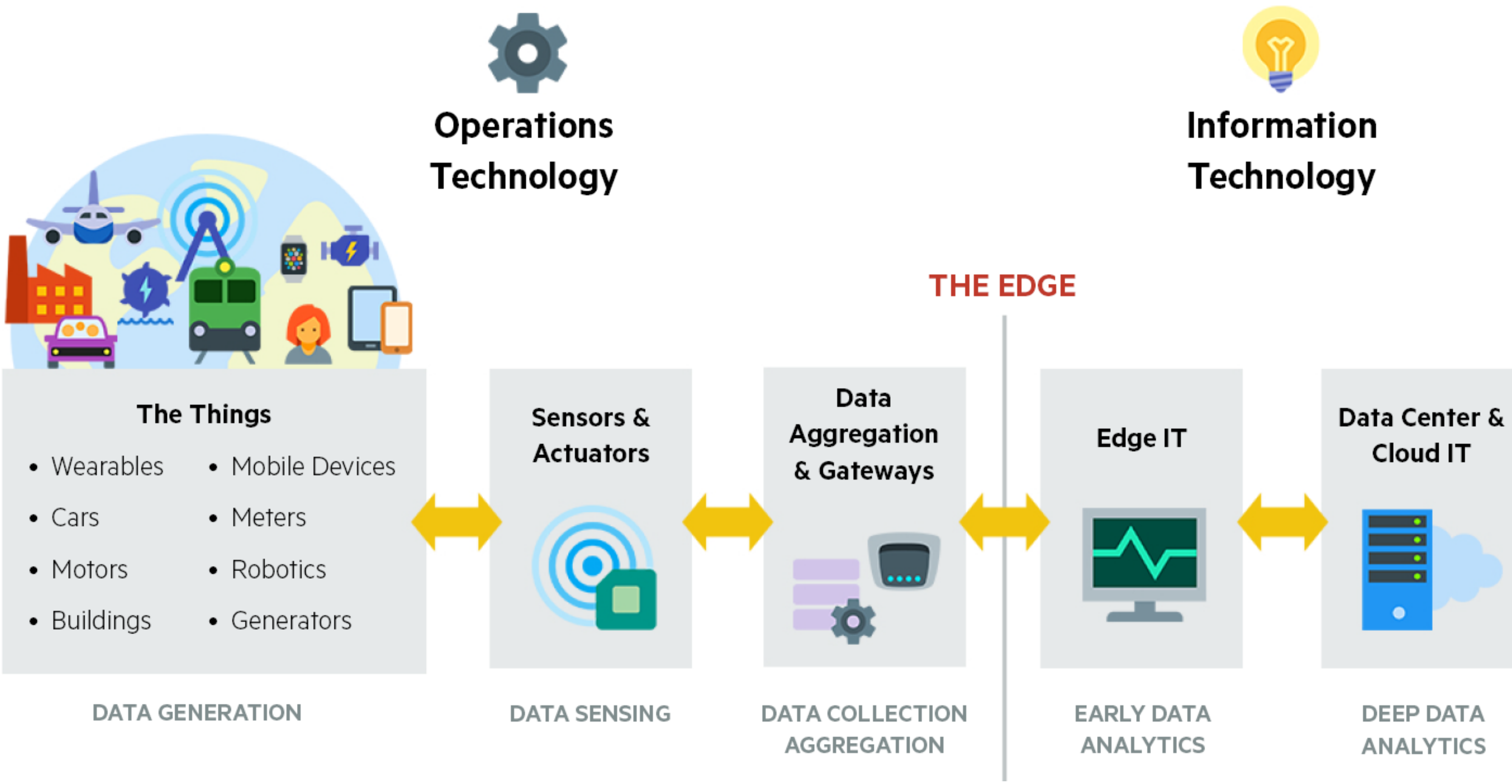

Limitations of traditional Cloud Computing

- **Network Bandwidth**: Sending large volume of data to centralized cloud servers may lead to network congestion.
- **Communication Latency**: The physical distance from the servers introduces substantial processing delays.
- **Resource Inefficiency**: Sending all the collected data to remote servers may be critical for energy-constrained devices.
- **Privacy and Security Concerns**: Continuous data transmissions to external servers may be a potential point of attack.

Emergence of Edge Computing

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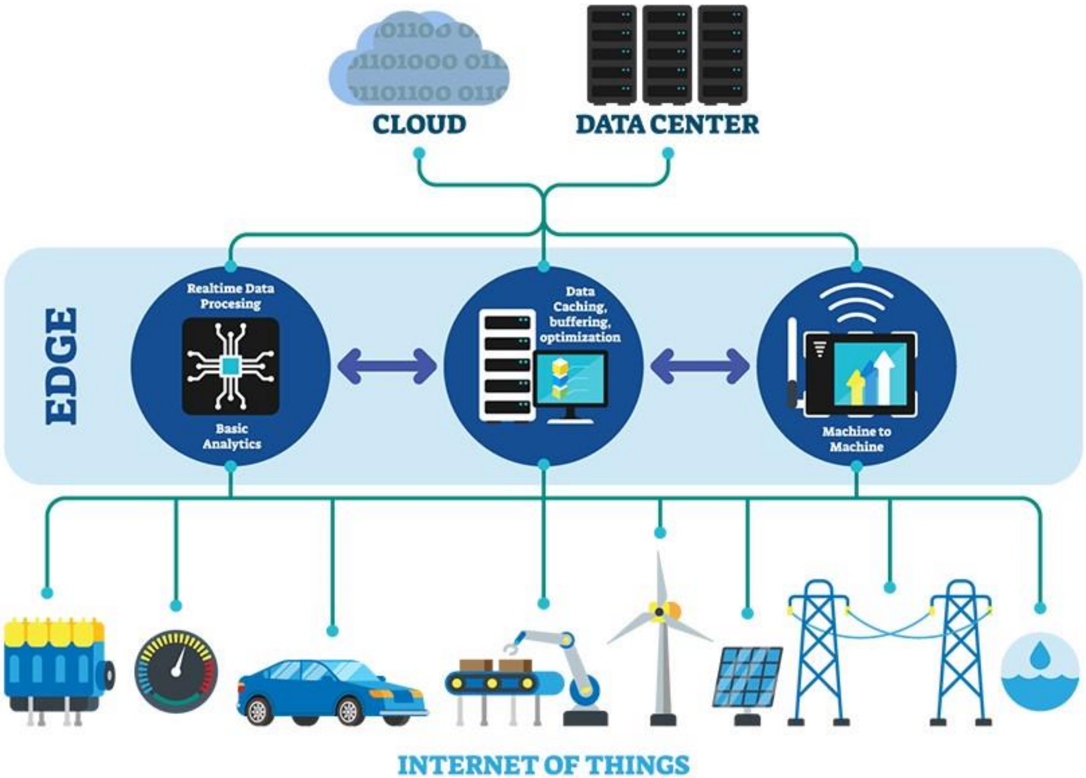
Key features:

- Proximity to data
- Reduced latency
- Real-time processing capabilities
- Enhanced energy efficiency and data security



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Computing paradigms

- **Centralized Cloud Computing**: Processes all data in remote servers.
- **Fog Computing**: Localized processing on network devices like routers.
- **Cloudlet Computing**: Small servers near IoT devices for low-latency tasks.
- **Mobile Edge Computing (MEC)**: Computing at mobile network edges for real-time responses.
- **Mobile Ad Hoc Cloud (MAC)**: Dynamic use of nearby mobile devices for processing.
- **Hybrid Computing**: Combines cloud and edge for balanced performance.

A study on Mobile Edge Computing (MEC)

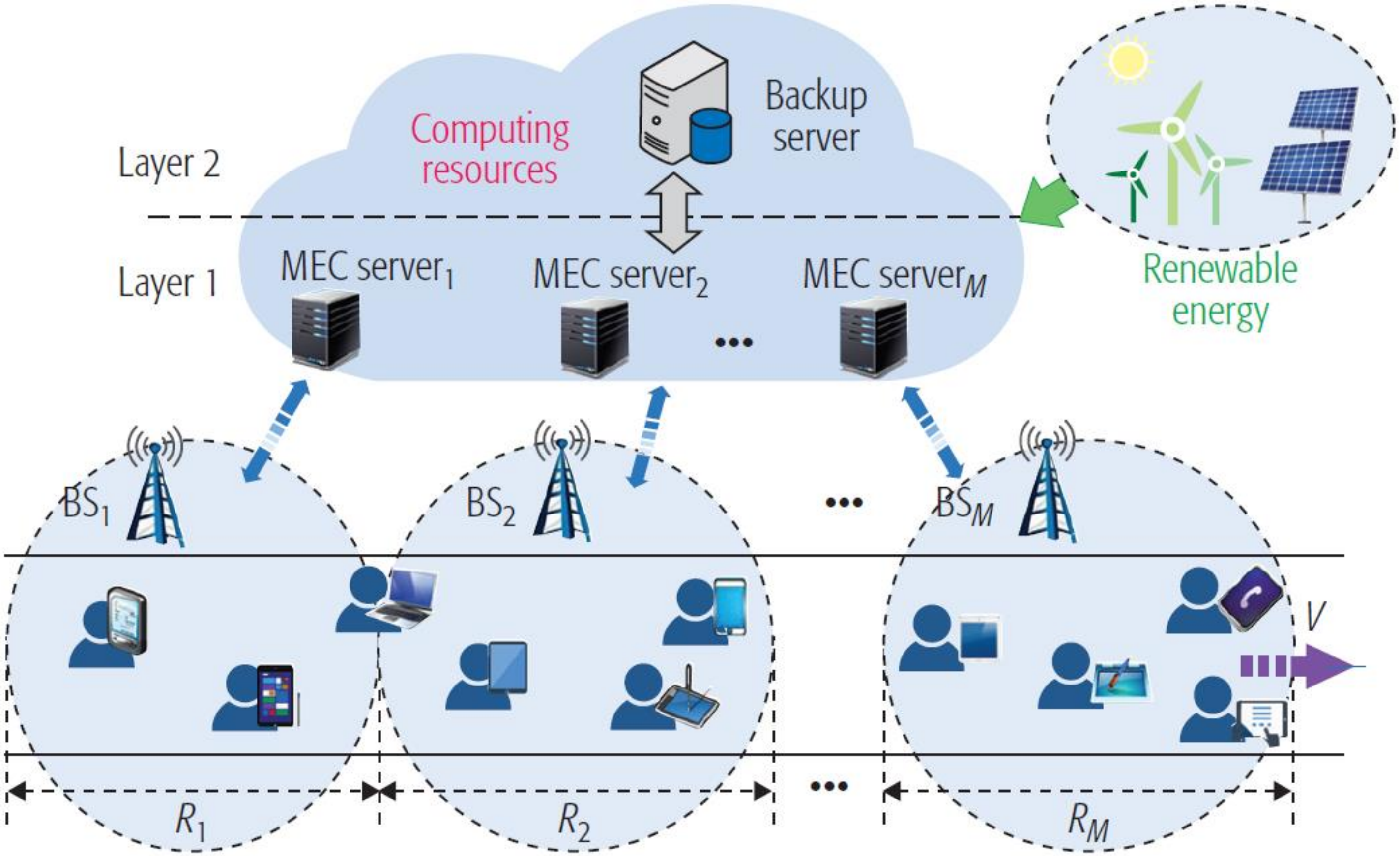

Figure 2. Mobility-aware hierarchical MEC framework.

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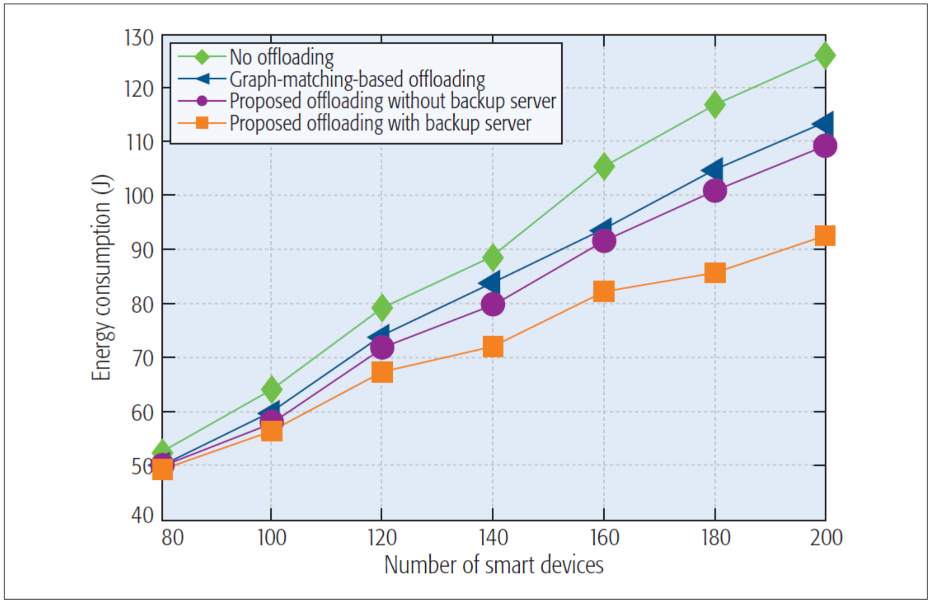

Figure 4. Energy consumption of the task execution with different schemes.

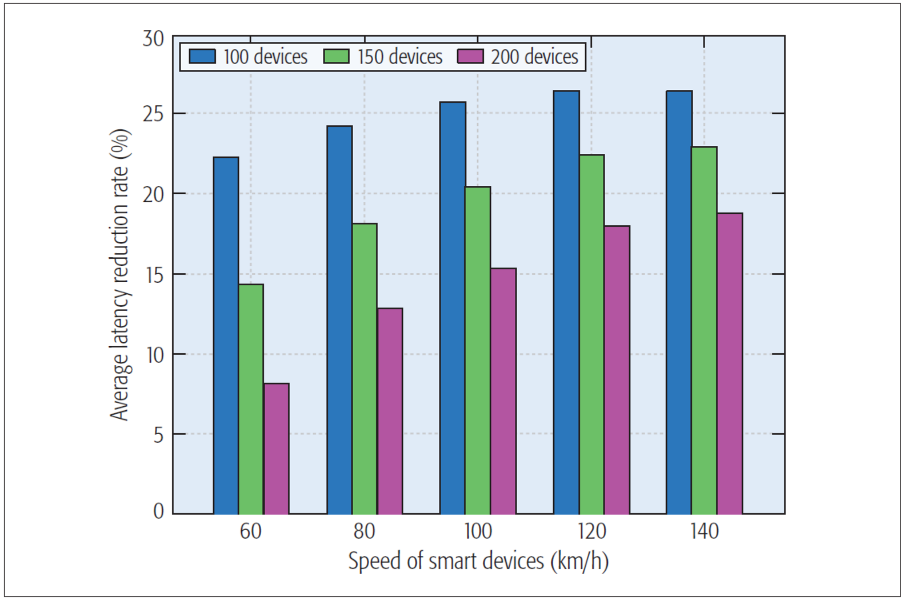

Figure 5. Comparison of average task latency reduction rates with various device speeds.

Edge computing applications

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A study on mobile gaming

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- **Objective**: Evaluate the impact of edge computing on latency in resource-demanding mobile gaming applications.
- **Experimental Setup**:
  - Platform: GamingAnywhere, an open-source cloud gaming framework.
  - Client Device: Google Nexus 5 mobile phone.
  - Server: Workstation with Intel Xeon E3-1230 CPU, 16GB RAM, and NVIDIA GPUs.
  - Network Technologies: Wi-Fi and LTE.
- **Comparison Scenarios**:
  - Local Edge Deployment: Server located at the network edge.
  - Specialized Cloud Infrastructure: Centralized cloud computing.
- **Key Metrics**: Response delay, comprising processing delay (PD), network delay (ND), and playout delay (PD).

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A study on mobile gaming

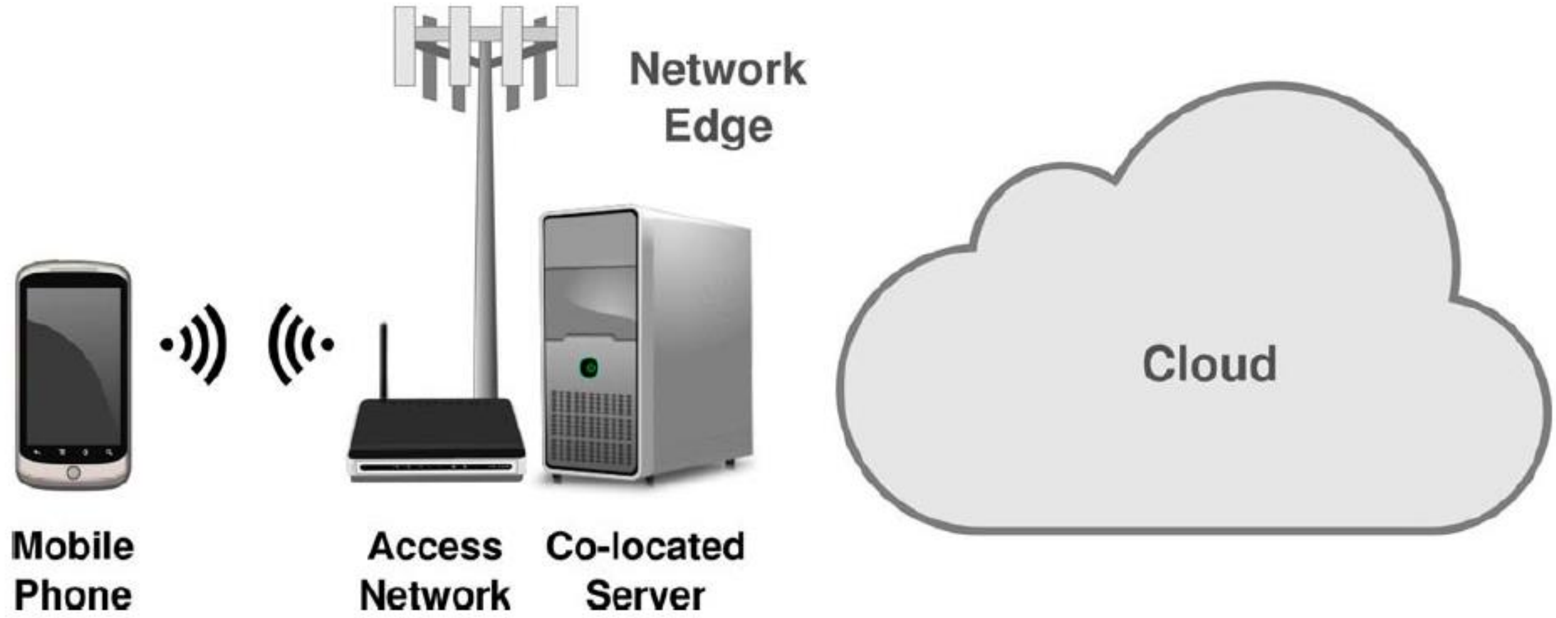

Fig. 2. Testbed setup used for the network edge scenario.

A study on mobile gaming

- **Findings**:
  - Latency: Edge setup achieved network delay (ND) of <20ms, outperforming cloud setups which showed >50ms delay.
  - Virtualization: Containers delivered near-bare-metal performance, while hypervisor virtualization incurred ~30% higher processing delay.
  - Resolution: Full HD processing times at the edge were significantly better compared to centralized cloud setups.
- **Implications**:
  - Edge computing enables high-quality gaming with latency <70ms, essential for immersive experiences.
  - Cloud setups, despite better computational resources, fall short in latency-critical scenarios like gaming.
- **Conclusion**: Proximity of computational resources in edge computing is critical for enhancing user experience in mobile gaming applications.

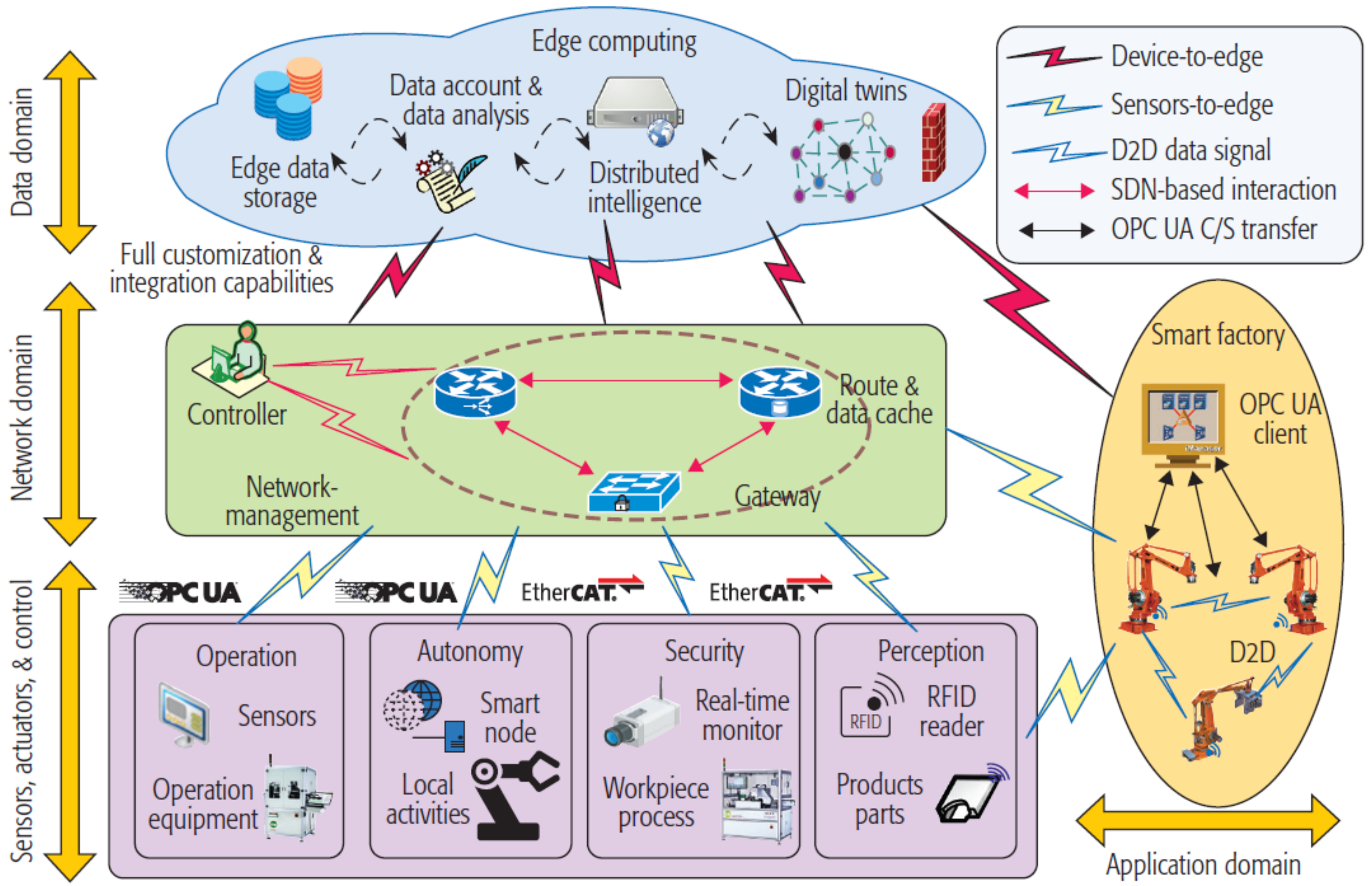

Figure 1. Architecture of an edge computing platform in IoT-based manufacturing.

A study on industrial manufacturing

- **Objective**: Explores the integration of edge computing in IoT-based manufacturing to address latency, real-time analytics, and resource efficiency.

- **Key Benefits**:
  - **Active Maintenance**:
    - Enhanced responsiveness through localized processing.
    - Case study on candy packaging line showed a 60% reduction in network traffic (from 16-17 Mb/s to 5-6 Mb/s) with improved order handling efficiency.
  - **Cloud-Edge Cooperation:**
    - Cloud layers handle long-term data analysis, maintenance planning, and knowledge mining.
    - Edge layers focus on real-time processing, security, and immediate business logic execution, ensuring a balanced workload.

A study on industrial manufacturing

- **Implementation Challenges**:
  - Protocol compatibility across legacy and modern systems.
  - Real-time processing for time-sensitive manufacturing tasks.
  - Integration with existing infrastructure while ensuring scalability.

- **Future Directions**:
  - Evolution of digital twins for manufacturing optimization.
  - Enhanced autonomous systems for process management.
  - Continued development in network optimization for seamless edge-cloud integration.

Open research challenges

1. **Heterogeneity**: Need for standardized programming models for diverse devices.
2. **Resource Management**: Efficient allocation in dynamic, constrained environments.
3. **Security & Privacy**: Safeguarding sensitive data against evolving threats.
4. **Data Handling**: Efficient preprocessing of large IoT data volumes.
5. **System Reliability**: Ensuring consistent and scalable service delivery.

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