Edge Computing Benefits in Low-Latency IoT Applications

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Dipartimento Matematica

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Internet of Things

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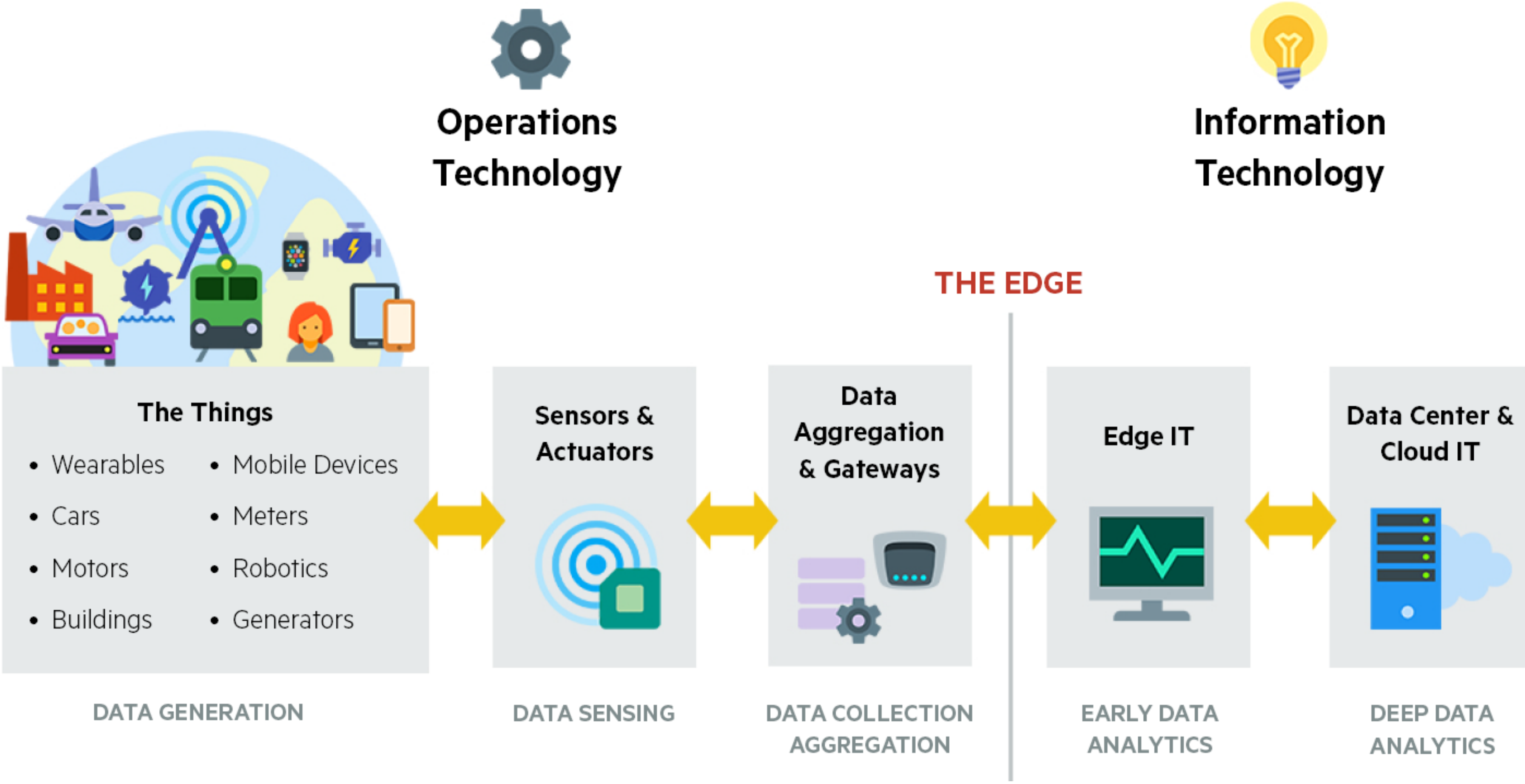

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Limitations of traditional Cloud Computing

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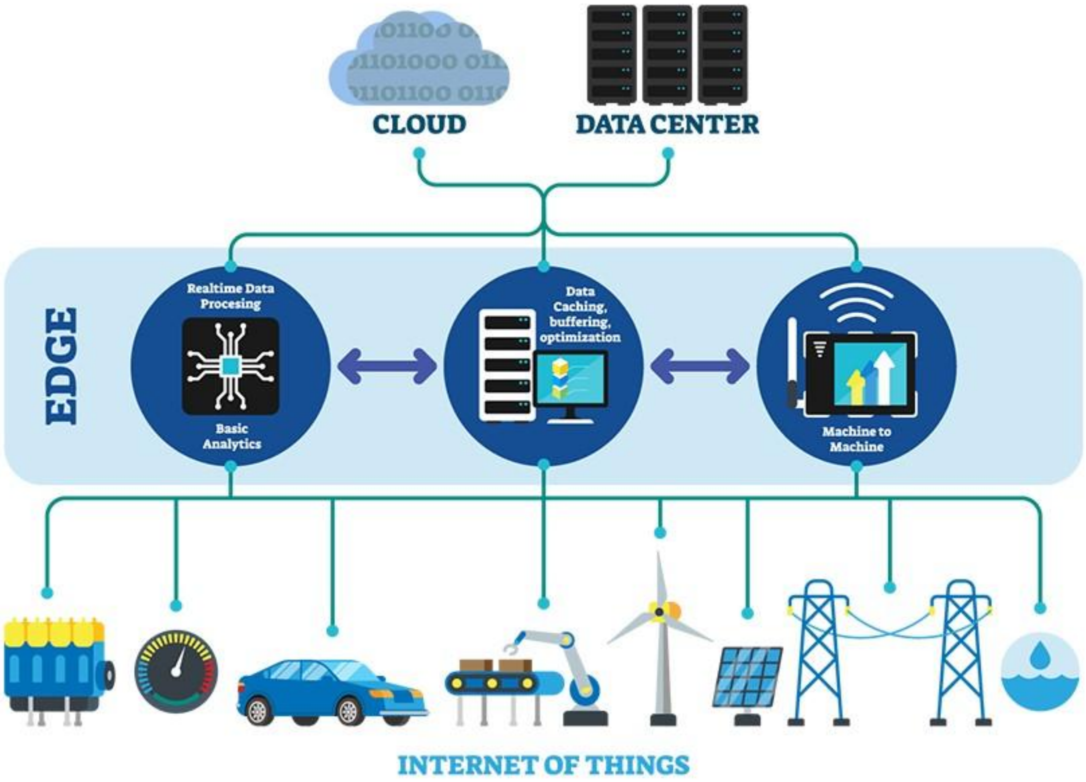
- **Network Bandwidth**: Sending large volume of data to centralized cloud servers may lead to network congestion.
- **Communication Latency**: The physical distance from the servers introduces substantial processing delays.
- **Resource Inefficiency**: Sending all the collected data to remote servers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

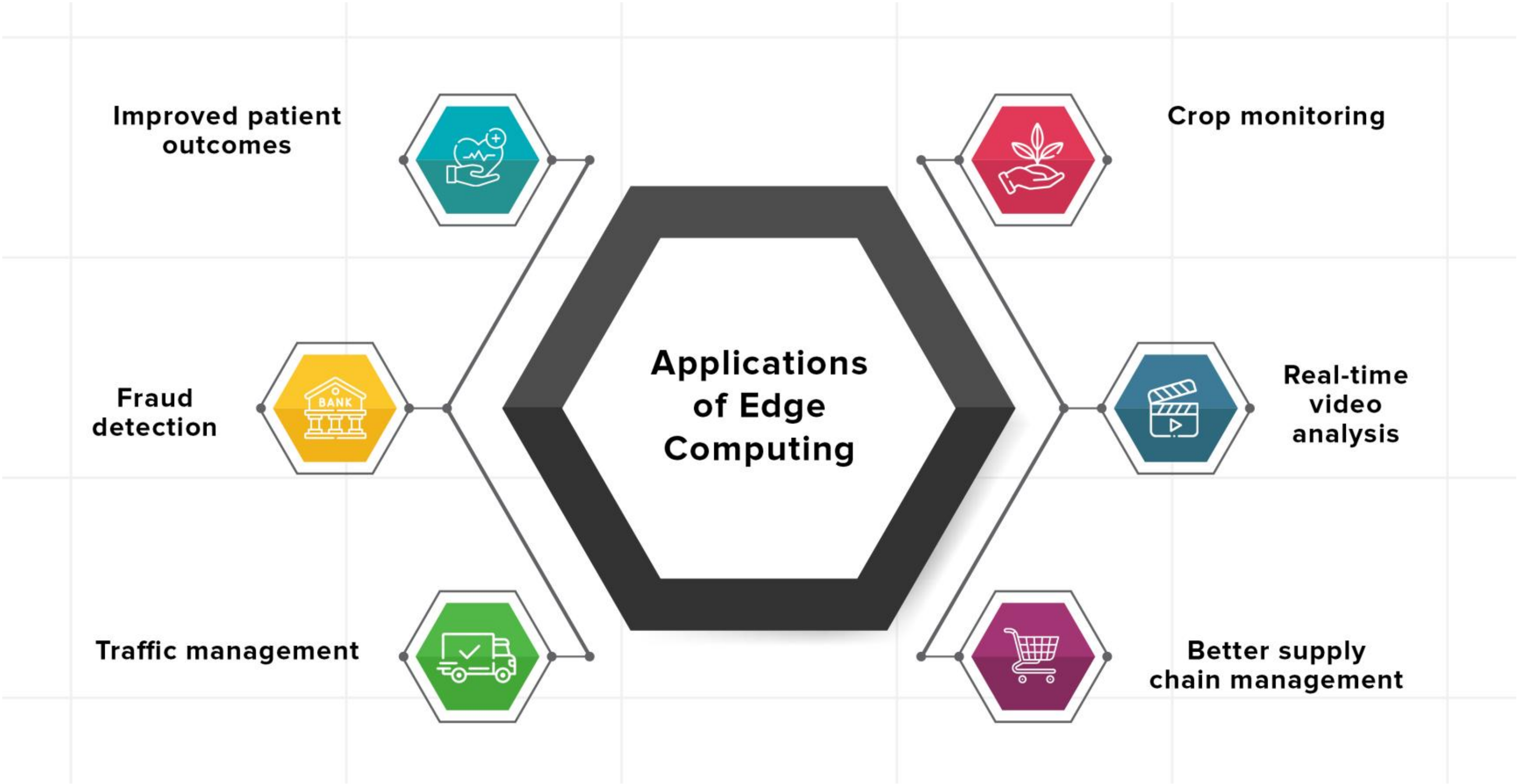
Emergence of Edge Computing

Key features:

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



Edge computing applications



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)

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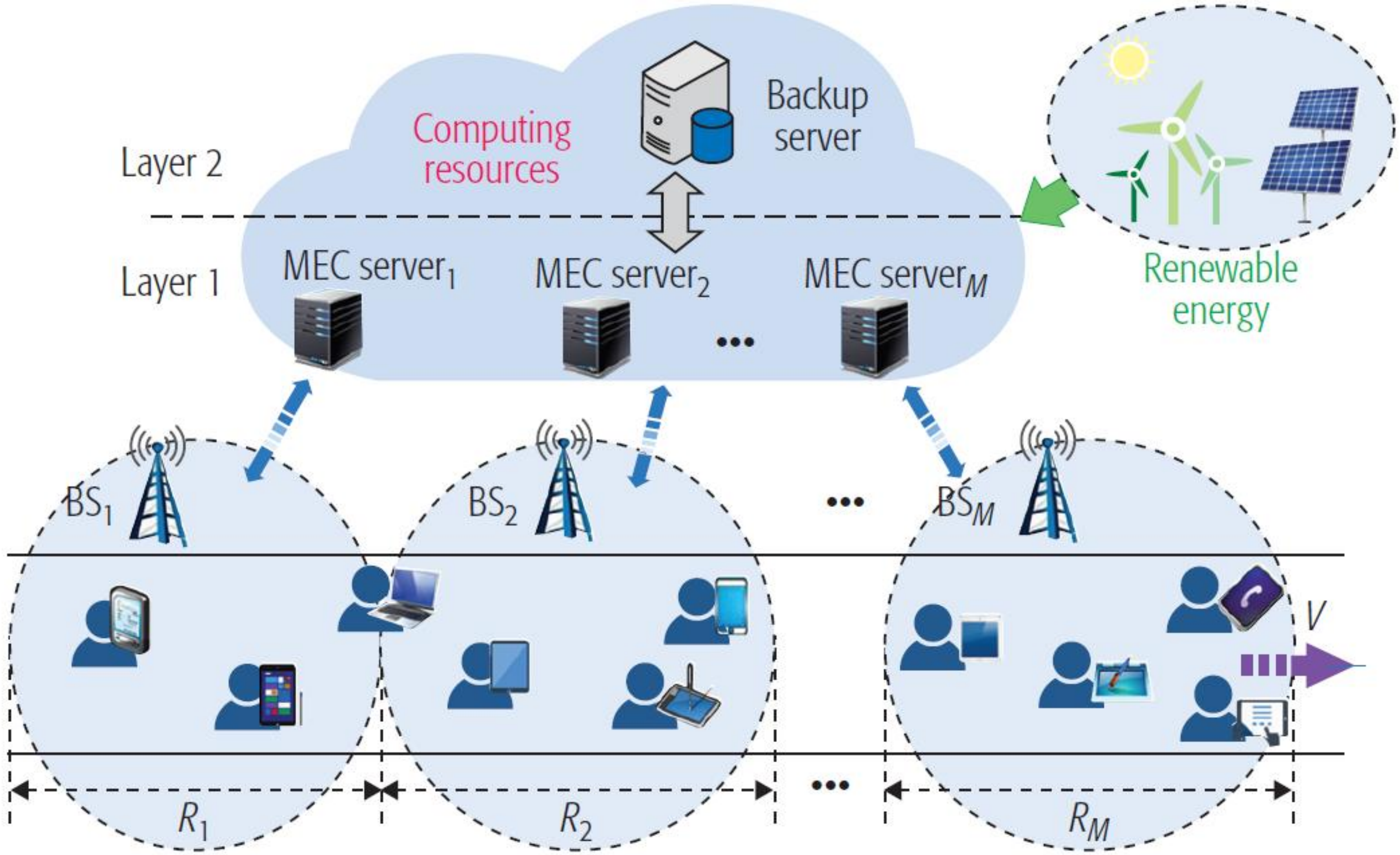

Figure 2. Mobility-aware hierarchical MEC framework.

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A study on Mobile Edge Computing (MEC)

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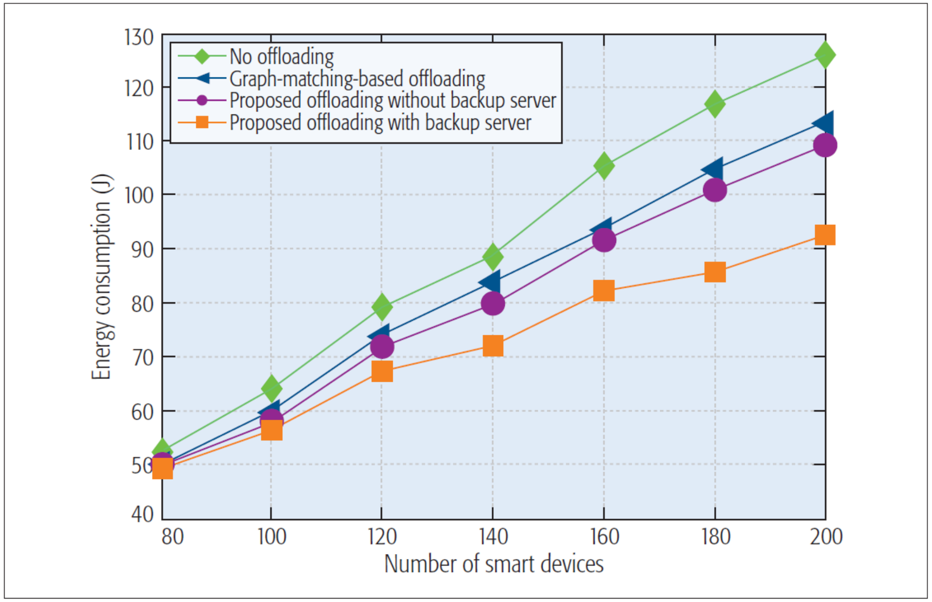

Figure 4. Energy consumption of the task execution with different schemes.

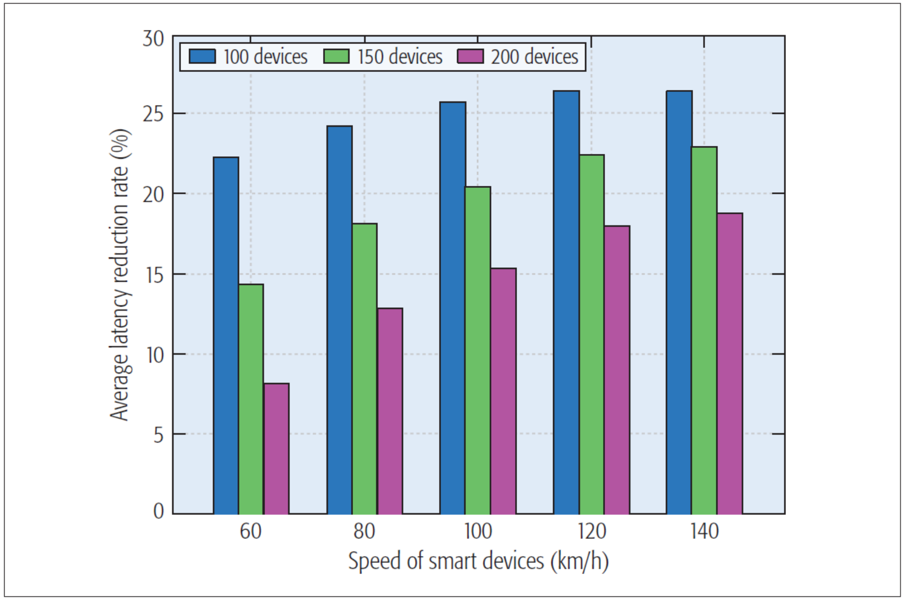

Figure 5. Comparison of average task latency reduction rates with various device speeds.

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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

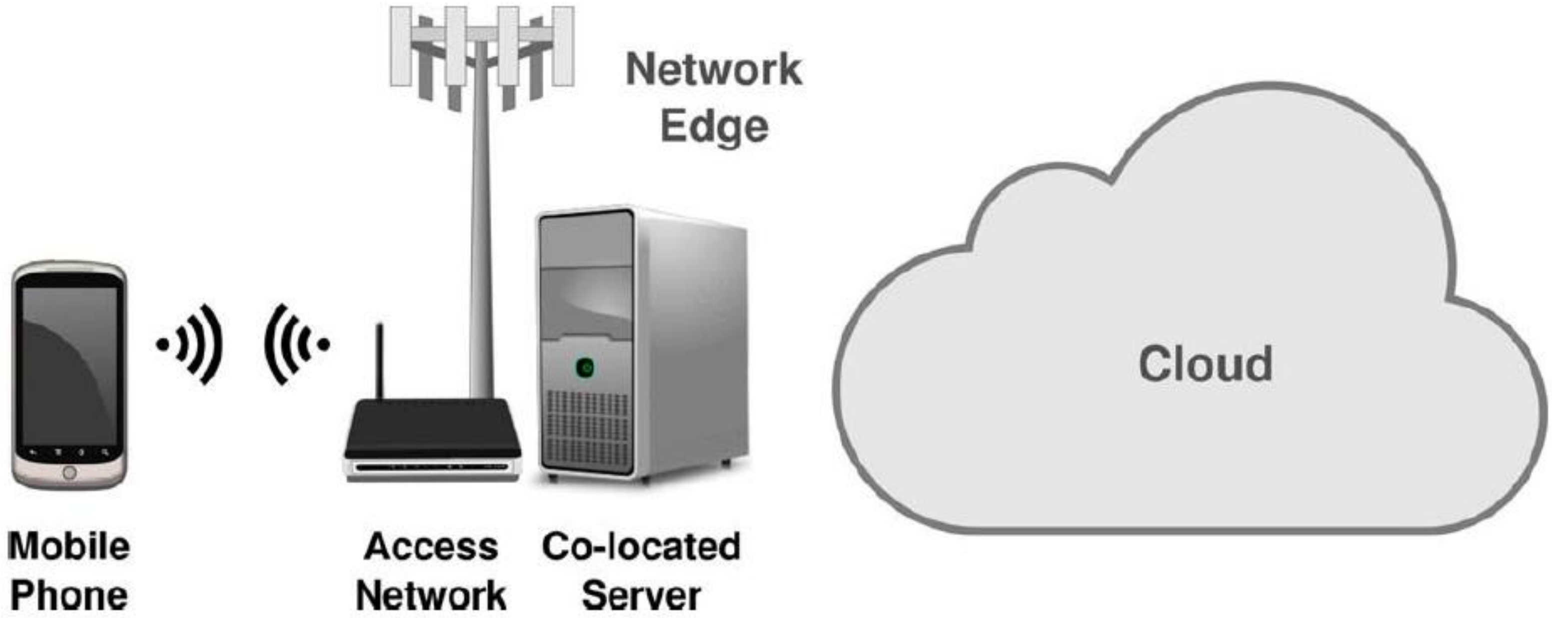

Fig. 2. Testbed setup used for the network edge scenario.

A study on mobile gaming

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- **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.
- **Conclusion**: Proximity of computational resources crucial to enhance the user experience.

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A study on industrial manufacturing

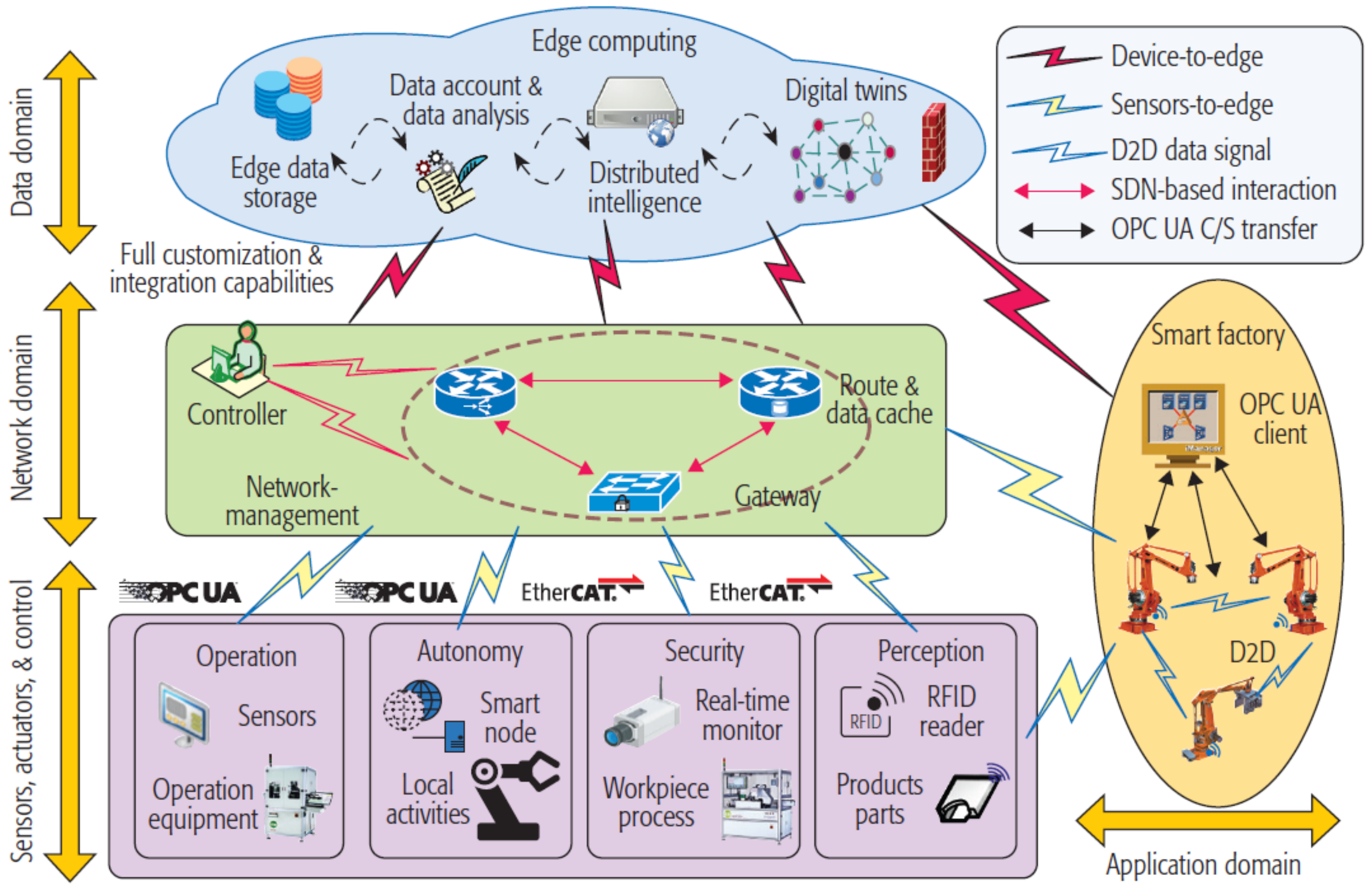

Figure 1. Architecture of an edge computing platform in IoT-based manufacturing.

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.

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

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

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