Edge Computing: Vision and Challenges

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Definition & Why Edge Computing

- Definition of Edge Computing:
  - Edge Computing refers to processing data near the source instead of relying on a centralized cloud.
  - Reduces latency, minimizes bandwidth usage, and improves real-time processing.
  - Edge devices include routers, gateways, micro data centers, and cloudlets.

- Why Edge Computing?
  - Push from Cloud Services:
    - Data growth exceeds network capabilities.
    - Centralized cloud models cannot handle real-time needs efficiently.
  - Pull from IoT:
    - Billions of IoT devices generating massive data streams.
    - Need for local data processing to reduce response time.

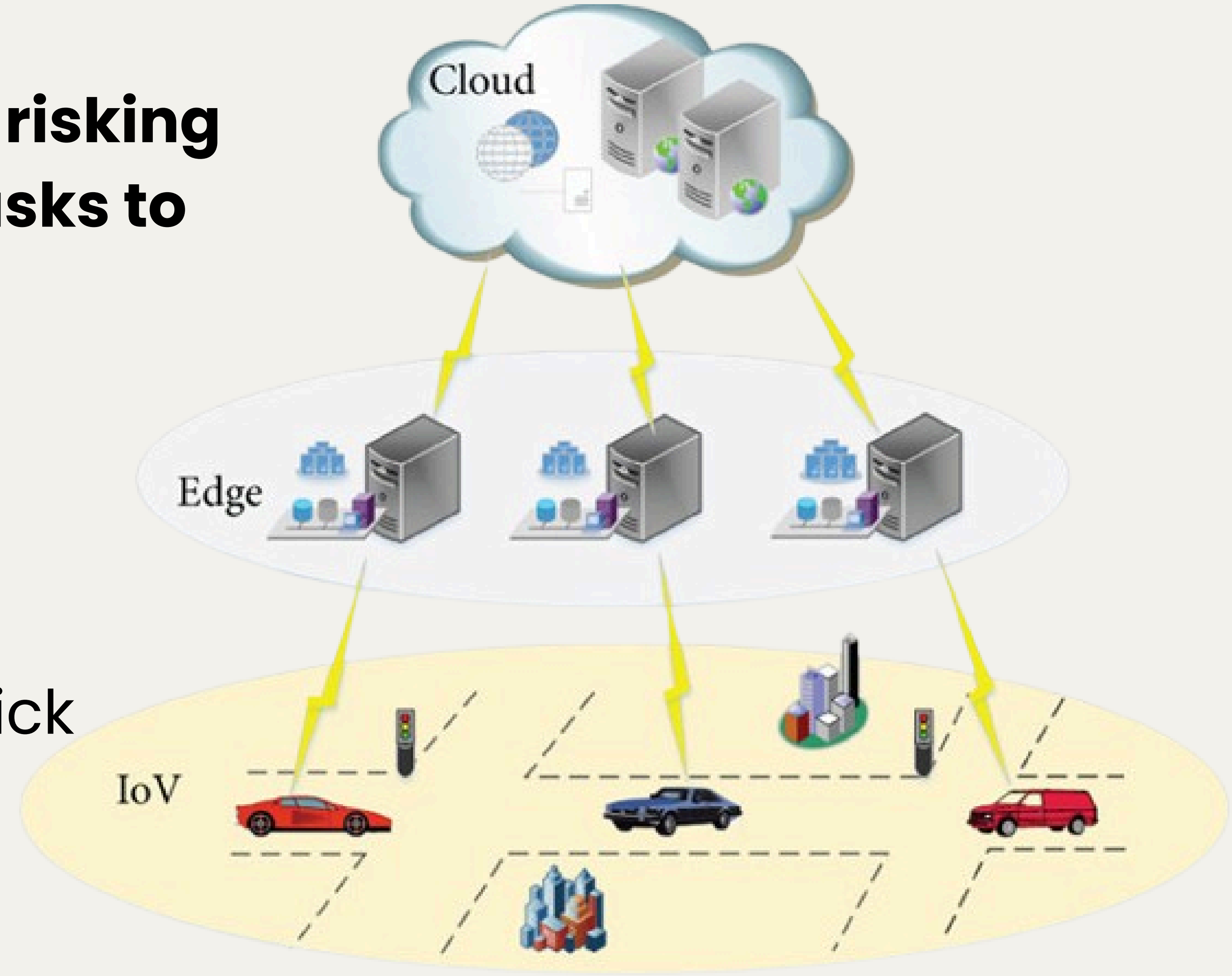
Comparison: Edge vs. Cloud Computing

Feature	Edge Computing	Cloud Computing
Latency	Low	High
Bandwidth Usage	Reduced	High
Privacy & Security	Higher	Lower
Processing Location	Near Data Source	Centralized
Scalability	Distributed	Highly Scalable
Cost Efficiency	Lower data transfer costs	High data transfer costs

Cloud Offloading

Case Studies

Traditional cloud computing sends all data to a central hub, risking sluggish performance. Edge computing flips this, pushing tasks to nearby edge nodes to supercharge speed and delight users.



<u>Advantages</u>

1. ***Faster Response*:** Cuts wait times, a game-changer for mobile devices.
2. ***Smart Caching*:** Stores info and actions at the edge for quick access.
3. ***Enhanced Interaction*:** Fuels real-time tools like VR, gaming, and wellness apps with smooth operation.
4. ***Sync Hurdles*:** Switching between edge points can tangle data—research ahead!
    - **USE CASES:** *E-Commerce, Wayfinding, Live Tech*

Video Analytics

Case Studies

Cloud computing stumbles with video due to slow uploads and privacy woes. Edge computing tackles this by analyzing video right where it's captured, delivering speed and security.

- Edge devices process video locally, skipping bulky cloud transfers.
- **Example:** To find a lost child, city cameras scan footage on-site and send only results—not raw video—to the cloud, slashing time and sidestepping privacy issues.
- **Advantages:** Lightning-fast responses for emergencies, reduced bandwidth use, and data stays local.
- **Challenges:** Coordinating countless cameras and their data across edges.

USE CASES:

- *Safety, Entertainment, Surveillance*

Smart Homes
Case Studies

Enhancing Automation and Urban Infrastructure with Edge Computing

- Edge computing enables real-time processing of sensor data within homes.
- Reduces internet bandwidth usage by processing data locally on an EdgeOS.
- Enhances privacy by keeping personal data within the home.
- Example: A smart thermostat adjusting temperature based on local sensor data instead of cloud-based commands.

Smart Cities
Case Studies

- Edge computing optimizes large-scale urban infrastructure like traffic lights, surveillance cameras, and public safety systems.
- Processes data closer to the source, reducing latency for real-time applications like emergency response and transport systems.
- Example: A missing person search using Edge-based cameras, where footage is analyzed locally, reducing cloud dependency.

Collaborative Edge

- **Cloud Computing Challenges:** Privacy concerns & high data transportation costs.

- **Edge Computing:** Acts as a small data center, bridging cloud and end users.
- **Collaborative Edge:** Enables data sharing & collaboration across locations.

Use Case: Connected Health (Flu Outbreak)

- **Hospitals:** Update patient data in real time.
- **Pharmacies:** Share flu-related purchase records.
- **Benefits:** Improved healthcare accountability & efficiency.

Stakeholder Benefits

- ***Pharmacies:*** Optimize inventory & maximize profits.
- ***Pharmaceutical Companies:*** Adjust production & stock levels.
- ***CDC:*** Track flu spread & issue timely alerts.
- ***Insurance Companies:*** Modify policies based on outbreak trends & costs.

Challenges in Edge Computing

⚙️ Programmability

- Diverse hardware complicates development.
- Apps must support different runtimes.

📊 Data Abstraction

- Managing diverse IoT data formats.
- Balancing privacy with useful insights.

🔗 Service Management

- Handling multiple IoT services (DEIR).
- Ensuring reliability & scalability.

🔒 Privacy & Security

- Protecting devices from cyber threats.
- Ensuring secure data ownership.

Opportunities & Future Prospects

- **Opportunities**
  - Reduced Latency: Faster response time for critical applications (e.g., real-time traffic management).
  - Bandwidth Optimization: Less data sent to the cloud, reducing congestion.
  - Energy Efficiency: Offloading processing to Edge devices improves battery life for IoT devices.
- **Future Research Areas**
  - Collaborative Edge Computing: Interconnected Edge nodes sharing resources for better efficiency.
  - Data Privacy & Security: Developing frameworks to protect user data at the Edge level.
  - AI-Driven Edge Analytics: Deploying AI models directly on Edge devices for real-time decision-making.

Optimization Metrics

Workload Allocation in Edge Computing

Latency:

- Process workloads at the nearest layer for faster response.
- Example: Pre-process photos at the edge in smart cities to reduce upload time.

Bandwidth:

- High bandwidth reduces transmission time, especially for large data.
- Example: Smart homes process data locally to save bandwidth and improve reliability.

Energy:

- Offloading tasks reduces energy consumption compared to local computation.
- Example: Multi-hop transmission increases energy use, requiring optimal layer selection.

Cost:

- Edge computing reduces latency, energy, and improves throughput, benefiting service providers.
- Example: Cache popular videos at building-edge to free city-edge resources.
- Providers may charge based on data location, balancing profit and user acceptance.

CONCLUSION

- **Edge Computing Momentum**: Increasing shift from cloud to edge for faster, more efficient processing.
- **Enhanced Performance**: Reduced latency, improved reliability, and optimized bandwidth usage.
- **IoT & Mobile Evolution**: Transitioning from data consumers to both producers and consumers.
- **Smart Environment Advancements**: Boosting efficiency in homes, cities, and beyond.
- **Collaborative Edge Advantage**: Seamless integration between cloud and end users.
- **Bridging the Gap**: Supports both traditional cloud computing and global data sharing.
- **Key Challenges & Opportunities**: Focus on programmability, security, and optimization.
- **Future Outlook**: Edge computing is a critical pillar of next-gen digital infrastructure.

THANK YOU