

Complete IoT Architecture Types & Detailed Explanation

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1. BASIC IoT ARCHITECTURE MODELS

Model 1: Three-Layer Architecture (Simplest)

Layer 1: Perception Layer (Physical Layer)

Purpose: Interface with the physical world

Components:

- **Sensors:** Devices that detect and measure physical phenomena
 - Temperature sensors (DHT11, DHT22, DS18B20, LM35)
 - Humidity sensors (DHT series, HIH-4000)
 - Pressure sensors (BMP180, BMP280, MPX5700)
 - Light sensors (LDR, BH1750, TSL2561)
 - Motion sensors (PIR HC-SR501, RCWL-0516)
 - Proximity sensors (Ultrasonic HC-SR04, IR sensors)
 - Gas sensors (MQ-2 smoke, MQ-135 air quality, MQ-7 CO)
 - Accelerometers (ADXL345, MPU6050)
 - Gyroscopes (L3G4200D, MPU6050)
 - GPS modules (NEO-6M, NEO-7M, NEO-8M)
 - Current sensors (ACS712, INA219)
 - Voltage sensors (Voltage dividers, DC sensors)
 - Sound sensors (Microphones, decibel meters)

- Soil moisture sensors (Capacitive, Resistive)
- pH sensors (Analog pH meters)
- Flow sensors (Water flow, air flow)
- Biometric sensors (Fingerprint, heart rate, pulse oximeter)
- Camera modules (ESP32-CAM, Raspberry Pi Camera)
- **Actuators:** Devices that perform actions
 - DC motors (Brushed, brushless)
 - Servo motors (SG90, MG996R)
 - Stepper motors (28BYJ-48, NEMA 17)
 - Relays (5V relay modules, solid-state relays)
 - Solenoid valves (Water control, pneumatic)
 - LED indicators (Single color, RGB, LED strips)
 - Buzzers (Active, passive)
 - LCD/OLED displays (16x2 LCD, 128x64 OLED)
 - Speakers
 - Pumps (Water pumps, air pumps)
 - Heaters and coolers
 - Locks (Electromagnetic, solenoid)

- **Identification Technologies:**

- RFID tags and readers (125kHz, 13.56MHz)
- NFC modules (PN532, RC522)
- QR codes and barcode scanners
- Biometric identifiers

Characteristics:

- Direct interaction with physical environment
- Low power consumption requirements
- Often battery-operated
- Limited processing capability
- Analog and digital signal generation

Working Principle: Sensors convert physical parameters into electrical signals. These signals are conditioned (amplified, filtered) and converted from analog to digital format using ADC (Analog-to-Digital Converter). The

digital data is then ready for transmission to the network layer.

Layer 2: Network Layer (Transport Layer)

Purpose: Transmit data from perception layer to processing systems

Components:

A. Communication Technologies:

Short-Range Communication (< 100m):

1. Bluetooth Classic (802.15.1)

- Range: 10-100m depending on class
- Data rate: 1-3 Mbps
- Power: Medium to high
- Use cases: Audio streaming, file transfer, peripheral devices
- Topology: Point-to-point, piconet (1 master, 7 slaves)

2. Bluetooth Low Energy (BLE 4.0/5.0)

- Range: 50-100m (BLE 5.0 up to 240m)
- Data rate: 1-2 Mbps
- Power: Very low (coin cell battery for months)
- Use cases: Wearables, beacons, health monitors, proximity sensors
- Topology: Star, mesh (BLE 5.0)
- Features: Advertising, GATT profiles, connection-less

3. WiFi (802.11 b/g/n/ac/ax)

- Range: 50-100m indoors
- Data rate: 11 Mbps (b) to 9.6 Gbps (ax/WiFi 6)
- Power: High consumption
- Use cases: High bandwidth applications, video streaming, heavy data
- Topology: Star (infrastructure mode), mesh (WiFi mesh)
- Frequency: 2.4 GHz, 5 GHz, 6 GHz (WiFi 6E)

4. Zigbee (802.15.4)

- Range: 10-100m per hop
- Data rate: 250 kbps
- Power: Very low

- Use cases: Home automation, smart lighting, industrial control
- Topology: Mesh, star, tree
- Features: Self-healing mesh, up to 65,000 nodes

5. Z-Wave

- Range: 30m per hop, 100m with mesh
- Data rate: 100 kbps
- Power: Low
- Use cases: Home automation, security systems
- Topology: Mesh
- Features: 232 devices per network, encrypted

6. Thread

- Range: Similar to Zigbee
- Data rate: 250 kbps
- Power: Low
- Use cases: Smart home, Matter protocol compatible
- Topology: IPv6-based mesh
- Features: Self-healing, secure, low latency

7. NFC (Near Field Communication)

- Range: < 4cm (very short)
- Data rate: 424 kbps
- Power: Very low (passive tags need no battery)
- Use cases: Contactless payment, access control, pairing
- Modes: Read/Write, Peer-to-Peer, Card Emulation

Medium-Range Communication (100m - 1km):

1. WiFi HaLow (802.11ah)

- Range: Up to 1km
- Data rate: 150 kbps - 347 Mbps
- Power: Lower than traditional WiFi
- Frequency: Sub-1 GHz
- Use cases: Smart agriculture, industrial IoT

Long-Range Communication (> 1km):

1. LoRa (Long Range)

- Range: 2-5km (urban), 15km (rural)
- Data rate: 0.3-50 kbps
- Power: Very low (battery life 2-10 years)
- Use cases: Smart cities, agriculture, asset tracking
- Frequency: 433 MHz, 868 MHz (EU), 915 MHz (US)

2. LoRaWAN (Protocol for LoRa)

- Architecture: Star-of-stars
- Classes: A (lowest power), B (scheduled), C (always on)
- Security: AES 128-bit encryption
- Network capacity: Millions of devices

3. Sigfox

- Range: 10-50km
- Data rate: 100 bps (uplink), 600 bps (downlink)
- Power: Ultra-low
- Use cases: Asset tracking, environmental monitoring
- Message limit: 140 messages/day (uplink)

4. NB-IoT (Narrowband IoT)

- Range: Up to 10km
- Data rate: 250 kbps (downlink), 20 kbps (uplink)
- Power: Low
- Use cases: Smart meters, parking, tracking
- Network: Uses existing cellular infrastructure
- Coverage: Deep indoor penetration

5. LTE-M (LTE Cat-M1)

- Range: Similar to cellular
- Data rate: 1 Mbps
- Power: Low (better than regular LTE)
- Use cases: Wearables, medical devices, fleet management
- Features: Voice support, mobility, handover

6. 5G IoT

- Range: Variable based on frequency

- Data rate: Up to 10 Gbps
- Latency: < 1ms (Ultra-Reliable Low Latency)
- Use cases: Autonomous vehicles, industrial automation, AR/VR
- Features: Network slicing, massive IoT support

7. Satellite IoT

- Range: Global coverage
- Data rate: Low to medium
- Use cases: Remote areas, maritime, aviation
- Providers: Iridium, Globalstar, Inmarsat

B. Network Devices:

1. Gateways:

- Protocol converters
- Aggregate data from multiple sensors
- Edge processing capabilities
- Examples: Industrial IoT gateways, home automation hubs

2. Routers:

- Direct data packets
- Network address translation
- Firewall capabilities

3. Access Points:

- WiFi connectivity
- Multiple device connections
- Bridge between wired and wireless

4. Switches:

- Connect multiple devices in LAN
- Data link layer forwarding
- Managed vs unmanaged

C. Communication Protocols:

1. MQTT (Message Queuing Telemetry Transport)

- Type: Publish-Subscribe

- Port: 1883 (unencrypted), 8883 (encrypted)
- Overhead: Very low (2 bytes minimum)
- QoS Levels:
 - QoS 0: At most once (fire and forget)
 - QoS 1: At least once (acknowledged delivery)
 - QoS 2: Exactly once (guaranteed delivery)
- Components: Broker, Publisher, Subscriber
- Topics: Hierarchical structure (e.g., home/bedroom/temperature)
- Best for: Low bandwidth, unreliable networks, mobile

2. CoAP (Constrained Application Protocol)

- Type: Request-Response (like HTTP)
- Port: 5683 (UDP)
- Overhead: Very low
- Methods: GET, POST, PUT, DELETE
- Features: Observe pattern, resource discovery
- Best for: Constrained devices, low power networks

3. HTTP/HTTPS

- Type: Request-Response
- Port: 80 (HTTP), 443 (HTTPS)
- Methods: GET, POST, PUT, DELETE, PATCH
- Overhead: High compared to MQTT/CoAP
- Best for: High bandwidth, RESTful APIs

4. WebSocket

- Type: Full-duplex communication
- Port: 80, 443
- Features: Real-time bidirectional data
- Best for: Live dashboards, real-time notifications

5. AMQP (Advanced Message Queuing Protocol)

- Type: Message-oriented middleware
- Port: 5672
- Features: Reliable, queuing, routing, transactions
- Best for: Enterprise applications, critical data

6. DDS (Data Distribution Service)

- Type: Pub-Sub, real-time
- Features: Quality of Service, discovery
- Best for: Industrial control, military, aerospace

7. Modbus

- Type: Industrial protocol
- Variants: Modbus RTU (serial), Modbus TCP (Ethernet)
- Best for: PLCs, industrial sensors

8. OPC UA (OPC Unified Architecture)

- Type: Platform-independent industrial protocol
 - Features: Security, information modeling
 - Best for: Industry 4.0, interoperability
-

Layer 3: Application Layer (Processing & Services)

Purpose: Process, analyze, store data and provide services

Components:

A. Edge Computing:

- Processing at or near data source
- Reduces latency (< 10ms response time)
- Reduces bandwidth usage
- Local decision making
- Offline capability
- Examples: Industrial edge servers, smart gateways, edge AI processors

B. Fog Computing:

- Intermediate layer between edge and cloud
- Distributed computing resources
- Hierarchical architecture
- Better for geographically distributed systems

C. Cloud Computing:

Cloud Platforms:

1. AWS IoT Core

- Device SDK support
- Device shadows (digital twins)
- Rules engine for data routing
- Integration with AWS services (Lambda, S3, DynamoDB)
- Security with X.509 certificates

2. Microsoft Azure IoT Hub

- Device provisioning service
- IoT Edge for edge computing
- Device twins
- Integration with Azure services
- Azure Digital Twins for modeling

3. Google Cloud IoT Core

- Device management
- Protocol endpoints (MQTT, HTTP)
- Integration with Cloud Pub/Sub
- Dataflow for stream processing

4. IBM Watson IoT Platform

- Device management
- AI/ML integration
- Blockchain integration
- Industry-specific solutions

5. Open Source Platforms:

- ThingsBoard: Device management, visualization
- OpenRemote: Building automation
- Kaa IoT Platform: Enterprise IoT
- ThingSpeak: Data collection and visualization

D. Data Storage:

1. Time-Series Databases:

- InfluxDB: High write throughput, time-based queries

- TimescaleDB: PostgreSQL extension for time-series
- OpenTSDB: Hadoop-based, scalable
- Prometheus: Monitoring and alerting

2. NoSQL Databases:

- MongoDB: Document store, flexible schema
- Cassandra: Wide-column store, highly scalable
- Redis: In-memory, fast access, caching
- CouchDB: Document store, offline-first

3. SQL Databases:

- PostgreSQL: Feature-rich, reliable
- MySQL: Popular, widely supported
- SQLite: Lightweight, embedded

4. Data Lakes:

- Hadoop HDFS: Distributed file system
- AWS S3: Object storage
- Azure Data Lake: Analytics service

E. Data Processing:

1. Stream Processing:

- Apache Kafka: Distributed streaming, high throughput
- Apache Flink: Real-time stream processing
- Apache Storm: Distributed real-time computation
- AWS Kinesis: Managed streaming service

2. Batch Processing:

- Apache Spark: Fast, in-memory processing
- Apache Hadoop MapReduce: Distributed processing
- AWS EMR: Managed Hadoop framework

3. Message Queues:

- RabbitMQ: AMQP broker
- Apache ActiveMQ: Java-based messaging
- AWS SQS: Managed queue service

F. Analytics & AI:

1. Descriptive Analytics:

- What happened?
- Historical data analysis
- Dashboards and reports

2. Diagnostic Analytics:

- Why did it happen?
- Root cause analysis
- Correlation analysis

3. Predictive Analytics:

- What will happen?
- Machine learning models
- Forecasting
- Anomaly detection

4. Prescriptive Analytics:

- What should we do?
- Optimization algorithms
- Decision automation
- Recommendation systems

G. Visualization:

- Grafana: Time-series visualization
- Kibana: Elasticsearch visualization
- Tableau: Business intelligence
- Power BI: Microsoft analytics
- Custom dashboards: Web-based (React, Vue, Angular)

H. Application Services:

- User management and authentication
- Device provisioning and management
- Firmware over-the-air (FOTA) updates
- Alert and notification services
- Business logic implementation

- API gateways
 - Integration with third-party services
-

Model 2: Four-Layer Architecture (Most Common)

This adds a separate **Processing Layer** between Network and Application:

Layer 1: Perception Layer

(Same as three-layer model)

Layer 2: Network Layer

(Same as three-layer model)

Layer 3: Processing Layer (Middleware)

Purpose: Intelligent data processing and management

Functions:

- Data filtering and aggregation
- Data transformation and normalization
- Protocol conversion
- Device management
- Security and authentication
- Load balancing
- Service orchestration

Components:

- Event processing engines
- Complex event processing (CEP)
- Data enrichment services
- Business rule engines
- Workflow management
- Service bus

Layer 4: Application Layer

Purpose: User-facing applications and services

Types of Applications:

- Mobile applications (iOS, Android, cross-platform)
 - Web applications and dashboards
 - Desktop applications
 - Voice assistants (Alexa, Google Assistant)
 - Enterprise applications (ERP, CRM integration)
 - Analytics and reporting tools
 - Control and monitoring interfaces
-

Model 3: Five-Layer Architecture (Detailed)

Adds **Business Layer** on top:

Layers 1-4: Same as four-layer model

Layer 5: Business Layer

Purpose: Business logic, decision making, and value creation

Functions:

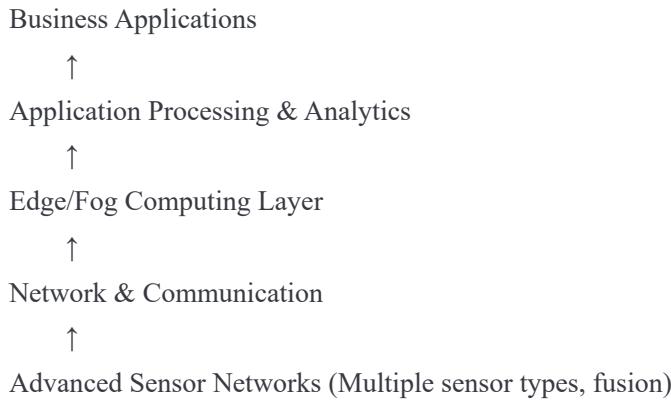
- Business process management
 - Revenue models
 - User management and billing
 - Service level agreements (SLA)
 - Compliance and governance
 - Business intelligence
 - ROI analysis and optimization
-

2. DETAILED LAYERED ARCHITECTURE MODELS

Architecture Type 1: Perception-Centric Architecture

Focus: Rich sensing and actuation

Structure:



Use Cases:

- Environmental monitoring
- Smart agriculture
- Industrial monitoring
- Healthcare monitoring

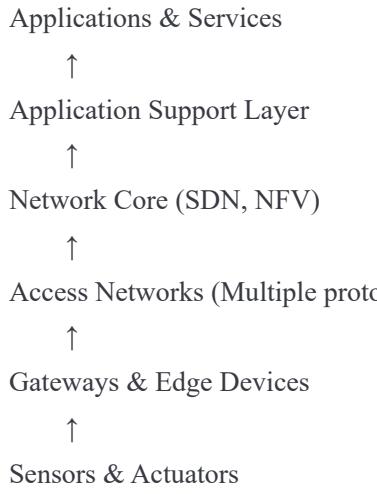
Characteristics:

- Large number of heterogeneous sensors
- Sensor data fusion
- Local preprocessing
- Redundancy for reliability

Architecture Type 2: Network-Centric Architecture

Focus: Communication and connectivity

Structure:



Use Cases:

- Telecommunications IoT
- Mobile IoT applications
- Wide-area monitoring
- Connected vehicles

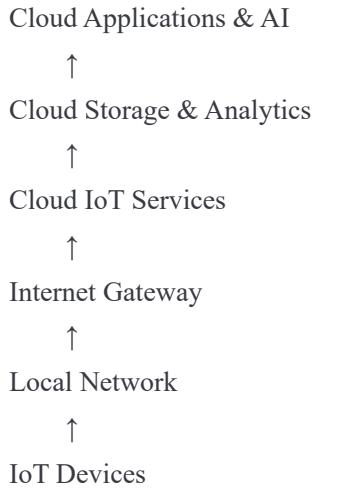
Characteristics:

- Software-defined networking (SDN)
- Network function virtualization (NFV)
- Multiple communication protocols
- Quality of Service (QoS) management
- Network slicing (5G)

Architecture Type 3: Cloud-Centric Architecture

Focus: Centralized processing and storage

Structure:



Use Cases:

- Consumer IoT (smart home)
- Non-real-time applications
- Data-intensive analytics
- Machine learning applications

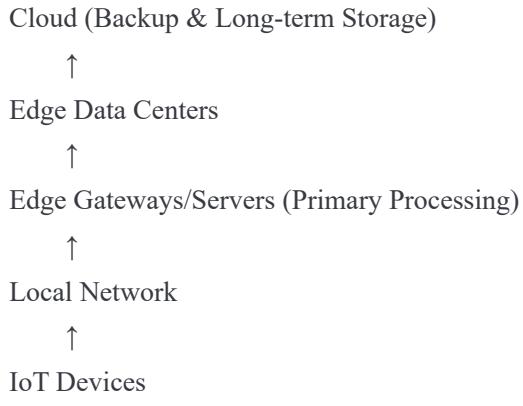
Characteristics:

- Centralized data processing
- Scalable computing resources
- Advanced analytics and AI
- Higher latency compared to edge
- Requires reliable internet connectivity

Architecture Type 4: Edge-Centric Architecture

Focus: Local processing and low latency

Structure:



Use Cases:

- Industrial automation
- Autonomous vehicles
- Augmented reality
- Real-time video analytics
- Safety-critical applications

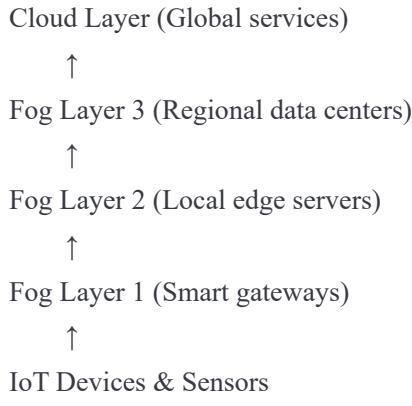
Characteristics:

- Ultra-low latency (< 5ms)
- Local data processing
- Offline capability
- Privacy and security
- Reduced bandwidth usage

Architecture Type 5: Fog Computing Architecture

Focus: Distributed, hierarchical processing

Structure:



Use Cases:

- Smart cities
- Connected vehicles
- Large-scale industrial IoT
- Distributed monitoring systems

Characteristics:

- Hierarchical architecture
- Load distribution
- Geographically distributed
- Supports mobility
- Balances latency and scalability

3. IoT REFERENCE ARCHITECTURES

3.1 IoT World Forum (IoT-WF) Reference Model

7-Layer Model by Cisco:

Level 1: Physical Devices & Controllers

- Sensors, actuators, devices
- Controllers (PLCs, microcontrollers)

Level 2: Connectivity

- Communication and connectivity
- Protocol translation

- Switching and routing

Level 3: Edge (Fog) Computing

- Data filtering and reduction
- Evaluation and reformatting
- Local processing

Level 4: Data Accumulation

- Storage (databases)
- Event, data management

Level 5: Data Abstraction

- Aggregation and normalization
- Multiple data source access

Level 6: Application

- Reporting, analytics
- Control applications

Level 7: Collaboration & Processes

- People and business processes
 - Integrations with existing systems
-

3.2 ITU-T IoT Reference Model

4-Layer Model:

Application Layer:

- IoT applications for different industries

Service Support and Application Support Layer:

- Generic support capabilities
- Specific support capabilities

Network Layer:

- Networking capabilities for control and transport

Device Layer:

- Device capabilities for sensing and actuating
-

3.3 Industrial Internet Reference Architecture (IIRA)

By Industrial Internet Consortium:

Viewpoints:

1. Business Viewpoint:

- Business vision, values, objectives
- Stakeholder concerns

2. Usage Viewpoint:

- System activities and sequences
- Use cases

3. Functional Viewpoint:

- System components
- Functional capabilities

4. Implementation Viewpoint:

- Technologies and architectures
- Deployment patterns

5. System Characteristics:

- Safety, security, privacy
 - Resilience, scalability
-

3.4 Azure IoT Reference Architecture

Microsoft's Model:

IoT Devices:

- Hardware devices and sensors

Cloud Gateway:

- Protocol gateway
- Device connectivity

Stream Processing:

- Real-time data processing
- Rules engine

Storage:

- Warm storage (recent data)
- Cold storage (historical data)

User Interface:

- Dashboards
- Mobile apps

Business Applications:

- Integration with existing systems
 - Business logic
-

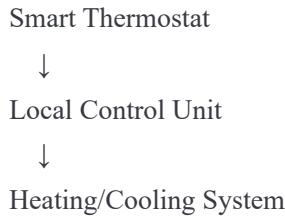
4. DEPLOYMENT ARCHITECTURE TYPES

4.1 Standalone IoT System

Structure:

- Self-contained system
- No external dependencies
- Local processing and storage

Example:

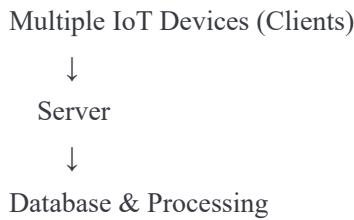


Use Cases:

- Embedded systems
 - Offline applications
 - Security-critical systems
-

4.2 Client-Server Architecture

Structure:

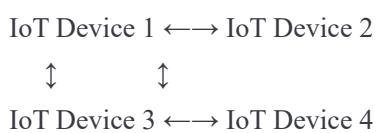


Characteristics:

- Centralized control
 - Clients send data to server
 - Server makes decisions
 - Traditional architecture
-

4.3 Peer-to-Peer (P2P) Architecture

Structure:



Characteristics:

- No central server
- Direct device-to-device communication
- Distributed decision making
- Resilient to single point of failure

Use Cases:

- Mesh networks
 - Home automation
 - Disaster recovery systems
-

4.4 Hybrid Architecture

Structure:



Characteristics:

- Combines multiple architectures
 - Flexibility in processing location
 - Optimized for specific requirements
-

5. COMMUNICATION ARCHITECTURE

5.1 Point-to-Point

Structure: Direct one-to-one connection

Example:



Protocols: Serial (UART), I2C, SPI

5.2 Star Topology

Structure: Central hub with multiple devices

Example:



Protocols: WiFi, BLE, Zigbee

Advantages:

- Easy to set up
- Easy troubleshooting
- Centralized management

Disadvantages:

- Single point of failure (hub)
- Limited by hub capacity

5.3 Mesh Topology

Structure: Devices interconnected

Example:



Protocols: Zigbee, Thread, BLE Mesh

Advantages:

- Self-healing
- Extended range
- No single point of failure
- Scalable

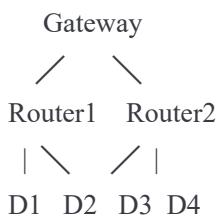
Disadvantages:

- Complex routing
 - Higher power consumption
-

5.4 Tree/Hierarchical Topology

Structure: Parent-child relationships

Example:



Use Cases:

- Industrial control systems
 - Building automation
-

5.5 Bus Topology

Structure: Single communication line

Example:



Protocols: Modbus, CAN bus

Use Cases:

- Automotive
 - Industrial automation
-

6. DATA FLOW ARCHITECTURE

6.1 Upstream Data Flow

Direction: Device → Cloud

Purpose:

- Telemetry data
- Sensor readings
- Status updates
- Alerts and alarms

Protocols:

- MQTT (publish)
- HTTP POST
- CoAP POST

Data Types:

- Temperature, humidity readings
 - GPS coordinates
 - Image/video data
 - Device status
-

6.2 Downstream Data Flow

Direction: Cloud → Device

Purpose:

- Commands and control
- Configuration updates
- Firmware updates (OTA)
- Queries

Protocols:

- MQTT (subscribe)

- HTTP polling
- WebSocket
- CoAP PUT

Data Types:

- Control commands (turn on/off)
 - Configuration parameters
 - Firmware binaries
 - Scheduling information
-

6.3 Bidirectional Data Flow

Most common in IoT:

Example Flow:

```
Device sends: Temperature = 25°C
Cloud processes: Temperature too high
Cloud sends: Turn on AC
Device confirms: AC turned on
Device sends: New temperature = 22°C
```

6.4 Device-to-Device Communication

No cloud involvement:

Example:

```
Motion Sensor → Smart Light
(directly)
```

Use Cases:

- Home automation
 - Industrial control
 - Emergency systems
-

7. SECURITY ARCHITECTURE

7.1 Defense in Depth (Layered Security)

Layer 1: Device Security

- Secure boot
- Hardware root of trust
- Secure element chips
- Tamper detection

Layer 2: Communication Security

- TLS/SSL encryption
- VPN tunnels
- Secure protocols (MQTT, HTTPS)
- Certificate-based authentication

Layer 3: Network Security

- Firewalls
- Intrusion detection systems (IDS)
- Network segmentation
- Access control lists (ACL)

Layer 4: Application Security

- Authentication (OAuth, JWT)
- Authorization (RBAC, ABAC)
- Input validation
- Secure APIs

Layer 5: Data Security

- Encryption at rest
- Encryption in transit
- Data anonymization
- Backup and recovery

Layer 6: Management Security

- Secure device provisioning
 - Key management
 - Certificate management
 - Security monitoring and logging
-

7.2 Zero Trust Architecture

Principles:

- Never trust, always verify
- Least privilege access
- Micro-segmentation
- Continuous monitoring

Implementation:

```
Device → Authentication → Authorization → Access
      ↓           ↓
Identity Verification Policy Check
```

8. SPECIALIZED ARCHITECTURE TYPES

8.1 Time-Sensitive Networking (TSN) Architecture

For real-time applications:

Characteristics:

- Deterministic latency
- Time synchronization (IEEE 1588)
- Traffic shaping
- Redundancy

Use Cases:

- Industrial automation

- Automotive
 - Audio/video streaming
-

8.2 Event-Driven Architecture

Structure:

Event Sources (Devices)



Event Bus/Broker



Event Processors



Actions/Responses

Characteristics:

- Asynchronous communication
- Loose coupling
- Scalability
- Real-time response

Example:

Motion detected → Event → Turn on lights

- Send notification
- Start recording

8.3 Microservices Architecture

For IoT applications:

Structure:

Device Management Service
Data Ingestion Service
Analytics Service
Notification Service
User Management Service

Characteristics:

- Independently deployable
 - Scalable
 - Technology diversity
 - Fault isolation
-

8.4 Serverless Architecture

Structure:



Characteristics:

- Event-triggered
- Auto-scaling
- Pay-per-use
- No server management

Use Cases:

- Data processing
 - Automation workflows
 - API backends
-

9. ARCHITECTURE SELECTION CRITERIA

Choose Based On:

1. Application Requirements:

- Real-time vs batch processing
- Latency requirements

- Data volume
- Reliability needs

2. Scale:

- Number of devices (100s vs millions)
- Geographic distribution
- Growth projections

3. Connectivity:

- Network availability
- Bandwidth constraints
- Mobility requirements

4. Power:

- Battery-operated vs powered
- Energy harvesting
- Power budget

5. Cost:

- Infrastructure costs
- Operational costs
- Maintenance costs

6. Security:

- Threat model
- Compliance requirements
- Data sensitivity

10. PRACTICAL ARCHITECTURE EXAMPLES

Example 1: Smart Home

Architecture Type: Star + Cloud-Centric

Structure:

Cloud (Alexa/Google Home)



Internet



WiFi Router (Hub)



Light Thermostat Camera

Components:

- WiFi-enabled devices
 - Cloud services for AI/voice
 - Mobile app interface
 - Local automation rules
-

Example 2: Industrial Monitoring

Architecture Type: Edge + Fog

Structure:

Cloud (Analytics, ML)



Edge Server (Local Processing)



Industrial Gateway



PLC Sensors Actuators

Components:

- Industrial protocols (Modbus, OPC UA)
 - Real-time processing at edge
 - Predictive maintenance
 - SCADA integration
-

Example 3: Smart Agriculture

Architecture Type: Hybrid (Edge + Cloud)

Structure:

Cloud (Long-term analytics)



LoRaWAN Gateway



LoRa Network



Soil Weather Irrigation

Sensor Station Controller

Components:

- Long-range communication
 - Solar-powered sensors
 - Local decision making
 - Cloud-based insights
-

Example 4: Connected Vehicle

Architecture Type: Mobile + Edge + Cloud

Structure:

Cloud Services