

Multi-Agent Architectures

Week 5: Collaborative AI Systems

PhD Course in Agentic Artificial Intelligence

Bloom's Taxonomy Levels

- **Remember:** Define multi-agent systems, coordination, communication
- **Understand:** Explain different agent topologies and roles
- **Apply:** Implement message passing between agents
- **Analyze:** Compare centralized vs. decentralized architectures
- **Evaluate:** Assess trade-offs in multi-agent design
- **Create:** Design a multi-agent system for a complex task

agent systems enable complex tasks beyond single-agent capabilities.

Multi

Why Multi-Agent Systems?

Single Agent Limitations

- Context window constraints
- No specialization (jack of all trades)
- Sequential processing bottleneck

Multi-Agent Benefits

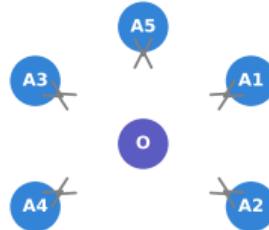
- Role specialization (expert agents)
- Parallel task execution
- Divide and conquer complex problems
- Emergent collective intelligence

of labor amplifies capabilities beyond individual agents.

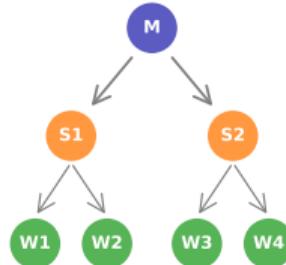
Divisi

Communication Topologies

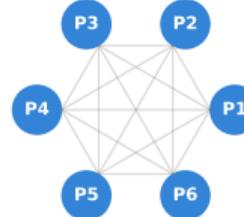
Centralized (Star)



Hierarchical



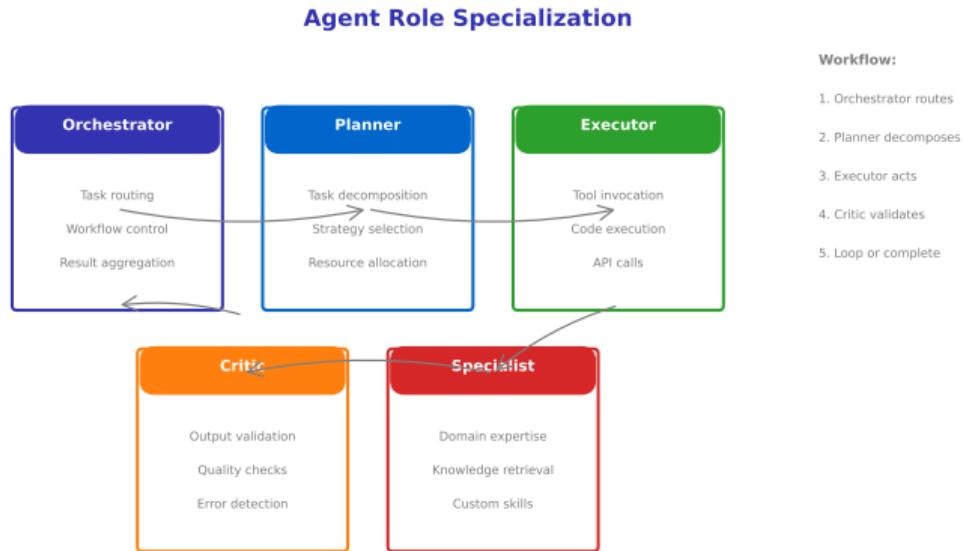
Peer-to-Peer (Mesh)



choice affects coordination overhead and flexibility.

Topo

Agent Role Specialization



roles enable division of cognitive labor.

Speci

Key Concepts (Wu et al., 2023)

- Conversable agents with defined roles
- Multi-turn message exchange
- Human-in-the-loop (human oversight) integration

Agent Types

- **AssistantAgent**: LLM-powered responder
- **UserProxyAgent**: Executes code, proxies human
- **GroupChat**: Multi-agent conversation manager

simplifies multi-agent orchestration with conversation patterns.

Key Idea (Hong et al., 2023)

- Agents simulate software development roles
- Product Manager, Architect, Engineer, QA
- Structured output protocols between roles

Communication Protocol

- Standardized documents (PRD = Product Reqs, Design Doc)
- Explicit handoff criteria between roles
- Version control for artifacts

protocols reduce miscommunication in multi-agent systems.

Struc

Key Idea (Qian et al., 2024)

- Chat-based software development simulation
- Phase-based workflow (Design, Coding, Testing)
- Role-play dialogues between agents

Phases

- ① **Design:** CEO + CTO discuss requirements
- ② **Coding:** Programmer + Code Reviewer iterate
- ③ **Testing:** Tester + Programmer fix bugs
- ④ **Documentation:** Technical writer finalizes

generates complete software from natural language specs.

Explicit Coordination

- Central orchestrator assigns tasks
- Defined protocols and interfaces
- Clear responsibility boundaries

Emergent Coordination

- Agents negotiate in shared environment
- Consensus through multi-round discussion
- Voting or debate to resolve conflicts

Hybrid Approaches: Structure where needed, flexibility elsewhere

coordination mechanism based on task predictability.

Request-Response

- Agent A sends query to Agent B
- B processes and returns result
- Simple, synchronous, easy to trace

Publish-Subscribe (event broadcast)

- Agents subscribe to topics
- Publishers broadcast to all subscribers
- Decoupled, scalable, event-driven

Shared Blackboard

- Common workspace all agents can read/write
- Good for collaborative problem-solving

choice depends on coupling, latency, and complexity needs.

Challenges in Multi-Agent Systems

Coordination Overhead

- Communication cost increases with agent count
- Synchronization delays
- Context management across agents

Failure Modes

- Cascading errors (one agent fails, chain breaks)
- Infinite loops (agents talking past each other)
- Conflicting actions (race conditions)

Mitigations: Timeouts, circuit breakers (failure isolation), conflict resolution

agent complexity requires robust error handling.

Best Practices

- ① Start with minimal agents, add as needed
- ② Define clear role boundaries
- ③ Use structured output formats
- ④ Implement graceful degradation
- ⑤ Monitor agent interactions

Anti-Patterns

- Too many agents for simple tasks
- Unclear responsibility boundaries
- No termination conditions

architectures are easier to debug and maintain.

Simp

This Week

- Tran et al. (2025). "Multi-Agent Collaboration Survey." arXiv:2501.06322

Supplementary

- Wu et al. (2023). "AutoGen." arXiv:2308.08155
- Hong et al. (2023). "MetaGPT." arXiv:2308.00352
- Qian et al. (2024). "ChatDev." arXiv:2307.07924

provides comprehensive overview; frameworks show implementation.

Survey

Summary and Key Takeaways

Key Concepts

- **Topologies:** Centralized, hierarchical, peer-to-peer
- **Roles:** Orchestrator, planner, executor, critic
- **Coordination:** Explicit protocols vs. emergent
- **Frameworks:** AutoGen, MetaGPT, ChatDev

Design Decisions

- When to use multi-agent vs. single agent
- Centralized vs. decentralized coordination
- Structured vs. free-form communication

Next Week: Agent Frameworks (LangGraph, CrewAI)

Multi

agent architectures enable complex collaborative intelligence.