Neapolis University Pafos

Course Code: IS509

Task 3: Academic Introduction to a Proposal

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November 26, 2025

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1 Introduction

Core Idea: Implementing structured, non-NLP agent communication in multi-agent systems.
In other words: replacing natural language with structured agent communication.

1.1 Background/context

Goal: Establish research territory (broad academic landscape + demo knowledge of the field)
Strategy: Relevant + credible sources + historical context with current issues + balance depth and breadth.

1.1.1 Broad context

The advancement of Large Language Models (LLMs) has ushered in a new era of autonomous AI agents capable of performing complex tasks with minimal human intervention [1]. Multi-agent systems (MAS) tend to outperform single-agent systems due to the larger pool of shared resources, coordination and specialization [2]. These systems can revolutionize industries by automating workflows and optimizing decision-making [3]. Businesses and individuals can leverage LLMs to build autonomous multi-agent systems with frameworks, such as AutoGPT, CrewAI, and Langchain [4] [5].

1.1.2 Narrow focus

However, current implementations of multi-agent systems predominantly rely on natural language processing (NLP) for inter-agent communication. Agent-to-agent communication through natural language introduces several challenges, including ambiguity, misinterpretation, and inefficiencies in task execution [6]. A pool of protocols and orchestration mechanisms for structured communication between agents exists [7].

Older agent communication standards. FIPA Agent Communication Language (ACL) defines a set of communicative acts and message structures for agent communication [8]. KQML (Knowledge Query and Manipulation Language) is another early standard that provides a framework for knowledge sharing and querying among agents [9]. Both are incopatible with modern JSON APIs and never saw wide adoption outside of academic circles.

Current solutions. OpenAI Agents SDK is an orchestration mechanism, growing adoption in OpenAI ecosystem, not an inter-agent communication protocol [10]. Model context protocol (MCP) by Anthropic provides a standardized way for AI models to connect with and use external tools and data sources - it is a client-to-agent protocol [11].

Emerging standard. With ACP's recent merger into Google's A2A under the Linux Foundation, A2A is rapidly becoming the dominant open standard for agent-to-agent communication [12]. In contrast to OpenAI Agents SDK, which provides only local IPC semantics, and the Model Context Protocol (MCP), which focuses on client-to-agent tool invocation, A2A is explicitly architected for distributed multi-agent systems. It defines message envelopes, routing, agent metadata, capability discovery, and extensible JSON-based interaction primitives [13].

1.1.3 Specific gap

A2A protocol provides a much-needed open standard for agent interoperability. However, like its predecessors—and much like KQML and FIPA-ACL before it—A2A standardizes only the syntax of communication, not its semantics. It does not prescribe performatives, ontologies, shared meaning representations, or reasoning-level guarantees. This semantic gap motivates research into typed, non-NLP communication layers that can enable more reliable, verifiable, and deterministic multi-agent behavior - exploring guarantees that agents understands each other beyond message structure.

1.1.4 Solution

We propose a typed, structured communication layer on top of the emerging A2A protocol. This layer introduces formal message semantics, performatives, and constraints to ensure deterministic agent interactions. Unlike current approaches that rely on natural-language wrappers, the proposed solution enforces verifiable communication rules, enabling agents to negotiate, coordinate, and delegate tasks reliably. The solution leverages A2A's existing transport, discovery, and lifecycle mechanisms, while filling the semantic gap that remains unaddressed.

1.2 Statement of the problem

Goal: Identify knowledge gaps(what remains unknown and unexplored $\rightarrow$ justify research).
LR $\rightarrow$ Gap analysis $\rightarrow$ problem statement/research aims.

Although A2A standardizes message envelopes, routing, and agent discovery, it does not define semantics, message types, or reasoning-level guarantees. This results in:

- Ambiguity in multi-agent task coordination;

- Unreliable negotiation and delegation;

- Susceptibility to prompt drift in LLM-based agents;

- Lack of formal verification of interactions.

Knowledge gaps: How can agents communicate deterministically and reliably without relying on natural-language prompts? Existing protocols (MCP, OpenAI Agents SDK) address tool or in-process communication, and historical protocols (KQML, FIPA-ACL) either failed to scale or are obsolete. We aim to build communication layers on top of A2A that add semantic guarantees, improving reliability and verifiability in MAS.

1.3 Justification of significance

Goal: Present my contribution to the field - how my research addresses these gaps and advance knowledge. **Strategy**: Magnitude + Urgency + Impact.

Structured, semantically precise communication in multi-agent systems is increasingly critical as agentic AI applications scale across industries.

1.3.1 Present evidence

- Multi-agent LLM systems are proliferating (LangChain swarms, AutoGPT)

- Current agent communication relies on natural language, causing hallucinations and inconsistencies

- Industrial deployments (edge robotics, supply chain agents, healthcare triage) require reliability and verifiability

1.3.2 Show consequences of inaction

Agents continue to misinterpret instructions, causing task failures;
Reduced trust in automated systems;
Inefficient deployment in critical sectors.

1.3.3 Connect to stakeholders

Researchers: fills a gap in MAS semantics;
Industry1: improves reliability of agent orchestration in real-world deployments;
Industry2: enhances singular human-to-agent communication capabilities with enhanced semantic reasoning;
Standardization bodies: informs evolution of A2A and successor protocols;

While this research primarily targets multi-agent system reliability, the proposed semantic layer also has potential downstream benefits for human-agent communication, enabling more precise interpretation of human intent, safer task execution, and reduced miscommunication in single-agent deployments.

1.4   Scope and limitations

Scope.   The research focuses on developing and evaluating a semantic layer for A2A-based multi-agent systems. It includes:

1. Defining typed messages, performatives, and constraints

2. Prototyping with LLM agents in simulated MAS environments

3. Evaluating reliability, consistency, and task success metrics

Constraints:
Resources required for model tuning and context handling;
Experiments limited to simulated or containerized environments; not full-scale industrial deployment.

1.4.1   Boundaries

Focused on horizontal agent-to-agent communication, not client-to-agent (MCP)
Semantic layer evaluated on a subset of representative tasks

1.4.2   Acknowledgement of constaints

Computational resources for LLMs may limit scale;
Security, privacy, and cross-organization deployment are out of scope;

1.4.3   Justify choices

Limiting to MAS-level semantics ensures feasibility within the research timeframe;
Using A2A as a base leverages a real-world standard while remaining future-proof;
Simulated environments provide reproducible and controlled evaluation;

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