A semantic framework for UAV interoperability based on STANAG 4586 standard

MSc thesis presentation

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Outline

- Introduction
- Problem Description
- Proposed Framework
- Application
- Implementation Details
- Simulation Results
- Conclusion

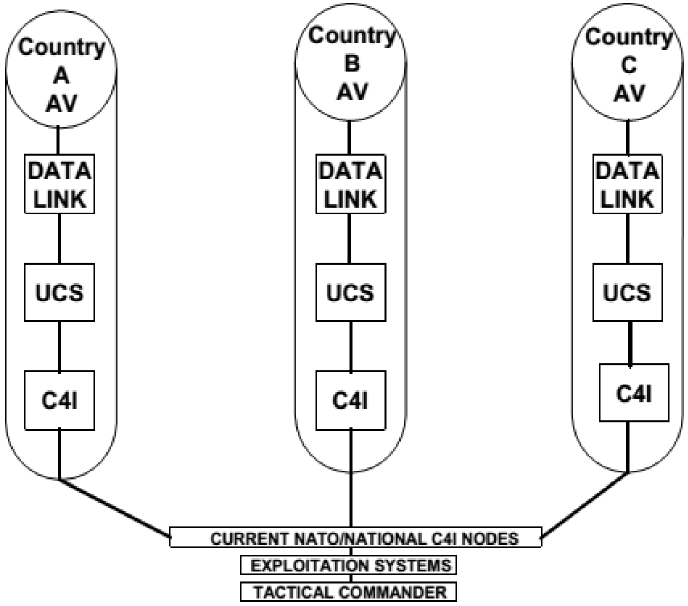
Introduction

- An Unmanned Aerial Vehicle (UAV) aims for the accomplishment of mission objectives.
  - operates autonomously or under remote control
  - alternative to manned aircrafts
    - cost effective
    - low risk
- However, a UAV is more that a mechanical device designed to accomplish a task.
  - Is part of a combined service environment of various deployed UAV systems (UAS)

Problem Description

- Current UAS are "stove-piped"
  - proprietary software and architecture
  - system-specific datalinks
  - unique communication protocols

- Heterogeneity of diverse UASs
  - impedes communication
  - hinders cooperation
  - requires complex infrastructures



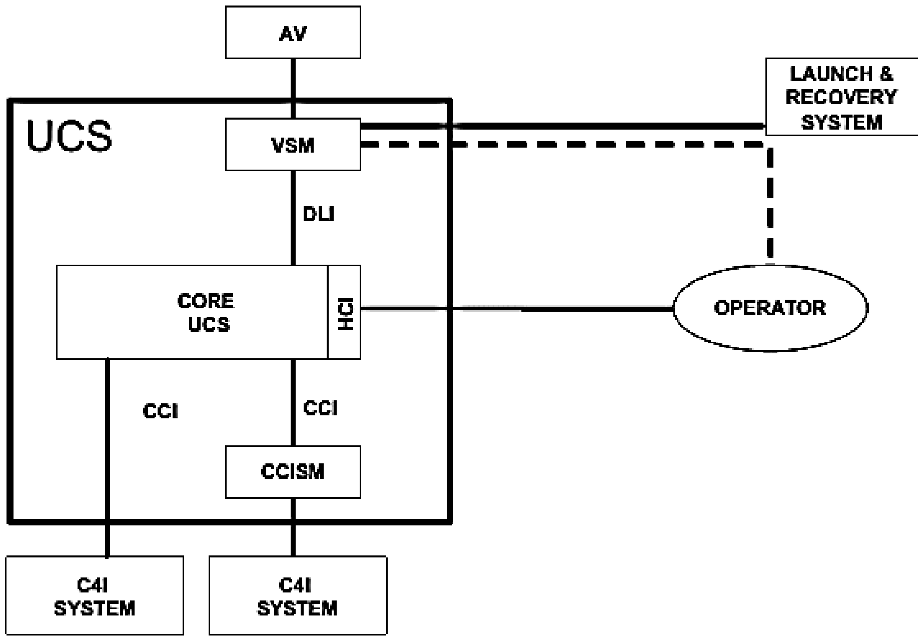
Interoperability is emerged as the most important policy to be achieved.

The concept of Interoperability

- Interoperability is characteristic of a system that can work with other systems
  - without restrictions
  - by the use of standards
- Armed Forces defines military interoperability
  - ability of nations to operate effectively together
  - achievement of a common task
- NATO proceeded to specification of STANAGs
  - address technical issues for UAV interoperability

NATO STANAG 4586

- The STANAG 4586 standard
  - specifies the architecture of an interoperable UAV Control System(UCS)
    - interfaces
    - functional elements
  - defines DLI and CCI interfaces
    - common data elements
    - generic message formats
  - Increases efficiency to mission accomplishment
    - mutual control
    - integration
    - joint utilization of information



Thesis Proposal

- Objective
  - Implementation of a STANAG 4586 compliant Ground Control Station (GCS)
    - capable of communication with different UAVs and GCSs
    - via STANAG DLI protocol
- Solution
  - A semantic framework for STANAG message (de)serializing
    - based on an OWL ontology
    - enables semantic interoperability between UAS elements
    - leveraged by STANAG 4586 specification
    - applicable by different UAV platforms e.g. ROS, JAUS, MAVLINK
- Application
  - A proof-of-concept system implementation that sends STANAG messages to control a MAVLink protocol UAV (MAV)
    - STANAG to MAVLink translation
    - borrows from UCS architecture
- Challenges
  - Analysis of STANAG 4586 specification
    - extensive documentation
    - avionics, military and technical terminology
  - STANAG to MAVLink bridge implementation
    - familiarization with MAVLink protocol
    - STANAG to MAVLink message mapping
      - not direct match
      - much of STANAG information is redundant to MAVLink

Domain Knowledge

- Methodology
  - Knowledge acquisition
    - about concepts on the domain of UAV systems
    - collection of informational sources
      - NATO STANAG 4586 specification document
      - technical manuals and STANAGs e.g. STANAG 7085
  - Specification and vocabulary construction
    - name entities extraction for the ontology design
      - based on the terminology of STANAG 4586
      - best practices for the naming of terms
  - Conceptualization
    - Models the domain concepts and identifies the relations between them
    - Definition of axioms and constraints
      - Universal, existential, cardinality and hasValue restrictions
      - Equivalent and disjoint classes
    - Specialization and field-specific relation types e.g. identity, reversibility
  - Ontology evaluation
      - By domain experts and automated reasoning tools (e.g. FaCT++)
      - Criterions e.g. clarity, consistency, coherence and minimal encoding bias

Ontological Model

ONTO_STANAG_4586 ontology

- A common formal vocabulary for:
  - architecture of a UCS
  - messages exchanged with UAV/external agents
  - level of interoperability each communication achieves
  - operational elements of a UAS

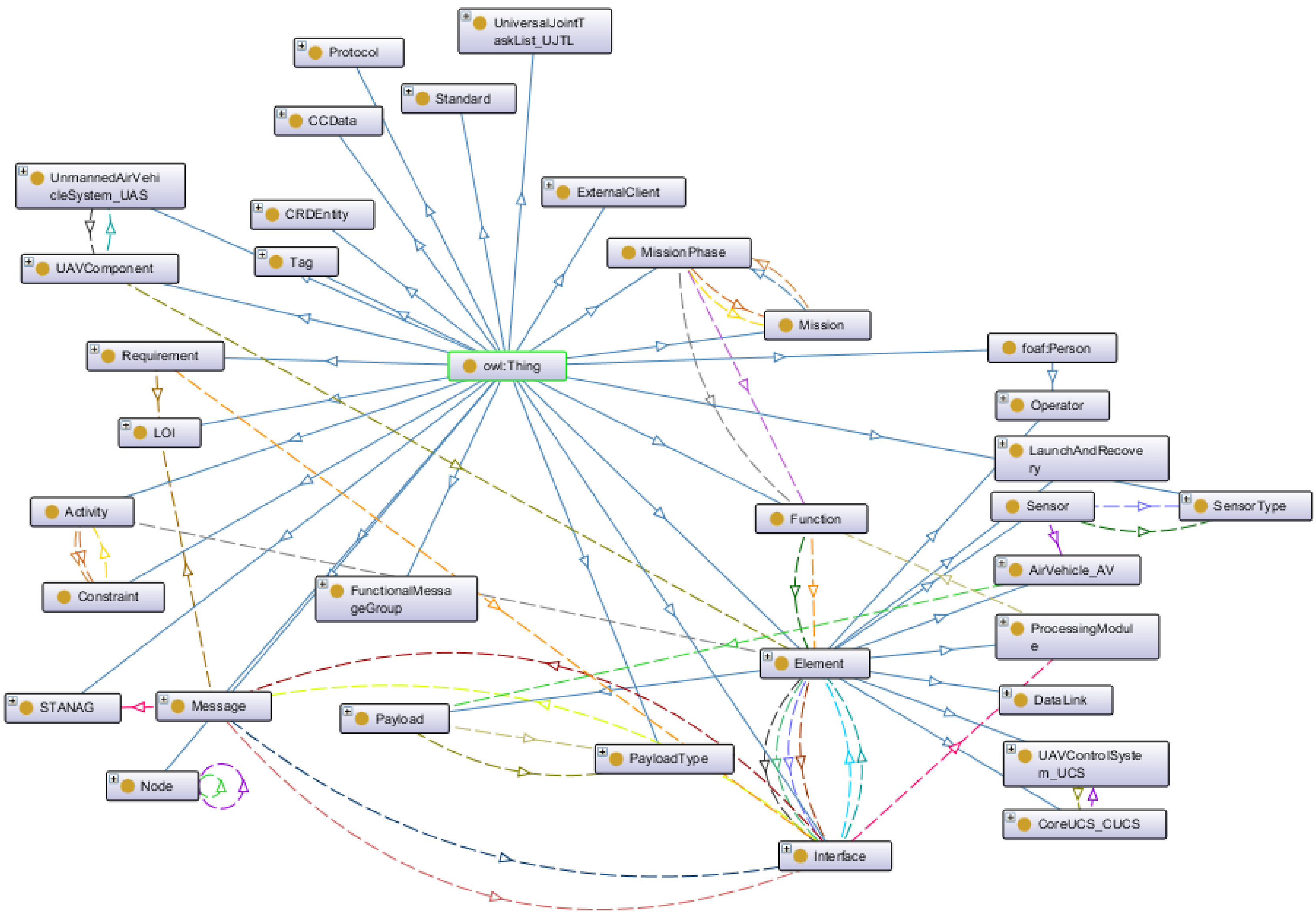
- Developed for use in the message communication between a GCS and a UAV
  - describes the structure of a message type and the information it stores

- Expressed in OWL
  - added expressiveness compared to other representation languages e.g. UML
  - reliable check using OWL reasoners

- Edited using Protégé

- Some metrics: 116 concepts, classified in 25 main classes, related by 45 object properties and 30 data attributes

The ONTO_STANAG_4586 ontology



STANAGOntoLib (1/2)

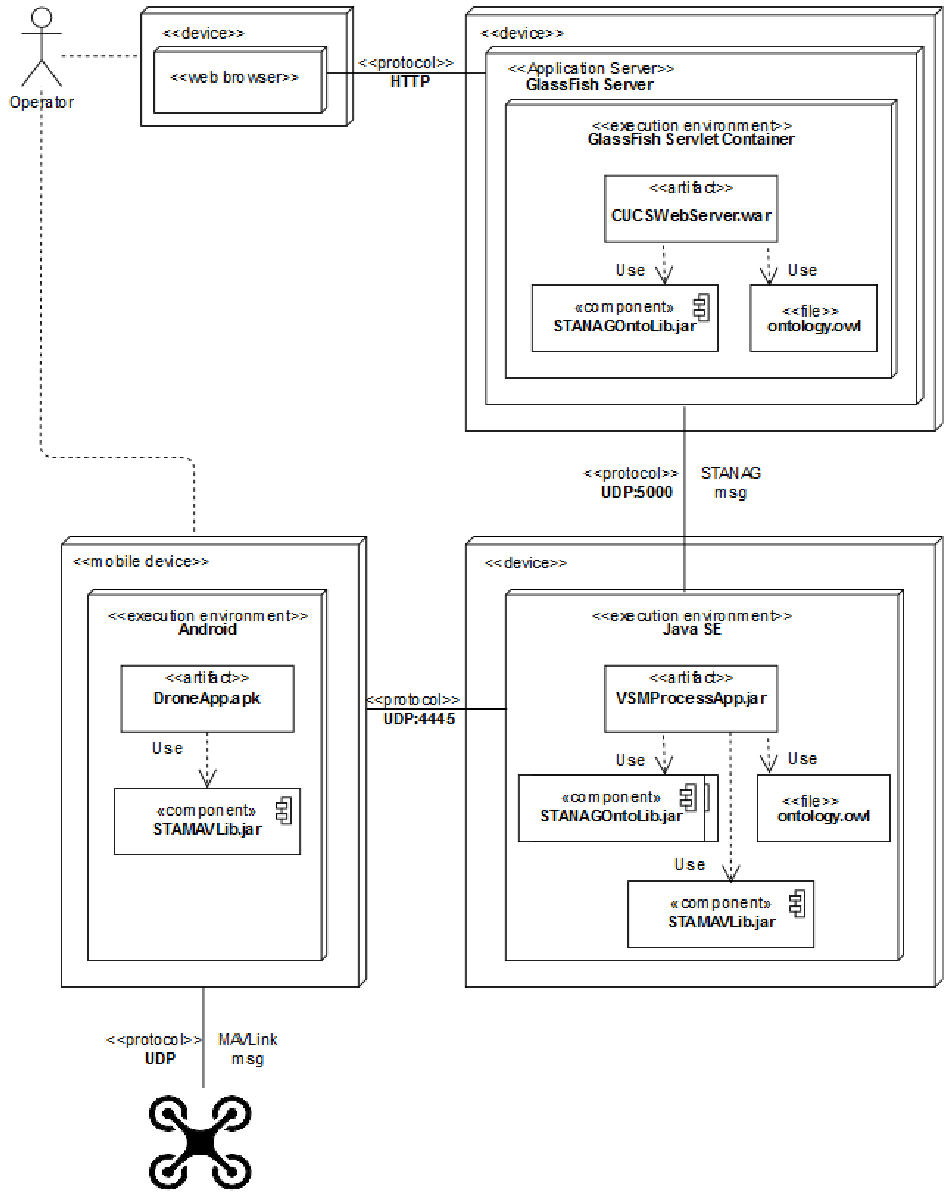
- A Semantic Web library for (de)serializing DLI messages
  - an encoded STANAG message as result of serialization process
    - given the input control data
  - a structure with the message's data as result of deserialization process
    - given the encoded STANAG packet
- Enables communication between diverse UAVs
  - by exchanging STANAG messages
- Exploits the ONTO_STANAG_4586 ontology
  - to extract the schema of a certain message type
    - by SPARQL queries execution

STANAGOntoLib (2/2)

Implementation

- A Java library with dependencies of:
  - .owl file of ONTO_STANAG_4586 ontology
  - ONT-API framework
    - a implementation of OWL-API over Apache Jena
    - solves the request of SPARQL query execution on an OWL ontology graph
- Conformed to the STANAG 4586 specification for the representation of data
  - standards e.g. time or earth position references
  - packaging, i.e. byte ordering
  - format e.g. the ID number of a UAS element
  - metric units

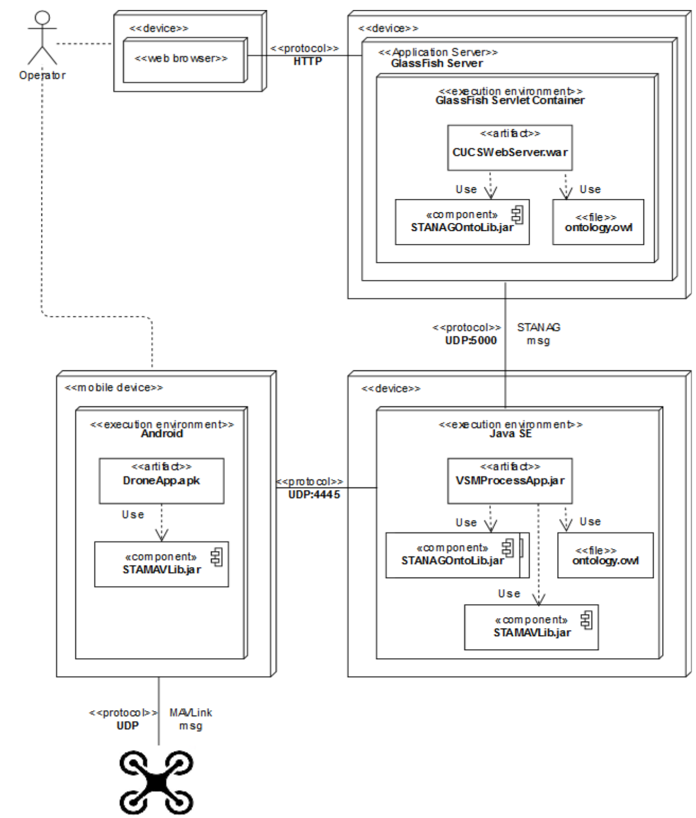
System Architecture



System Components

CUCSWebServer

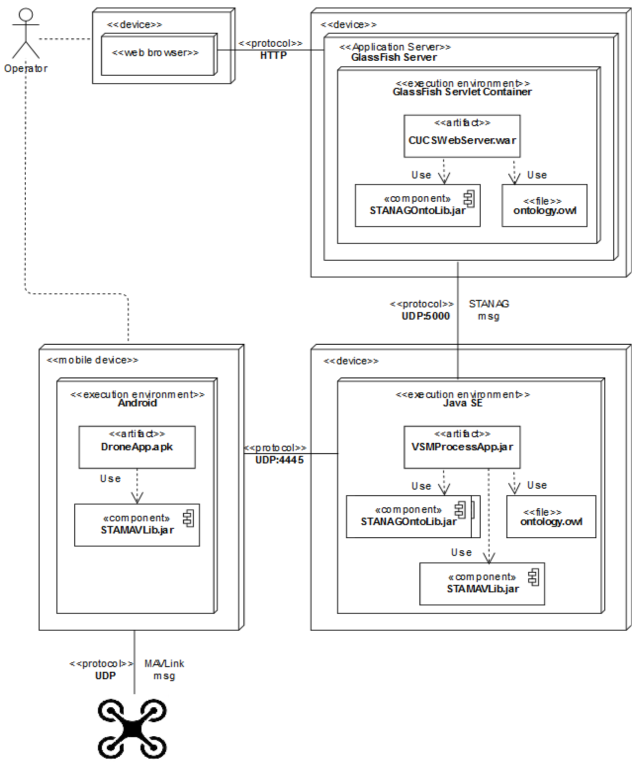
- A web graphical interface that imitates a STANAG 4586 compliant GCS
  - enables operator to control different types of UAVs
  - by sending the appropriate DLI messages
- Integrates functionality of STANAGOntoLib
- Communicates with VSMProcessApp over UDP/IP
  - through transmission of STANAG packets



System Components

VSMProcessApp

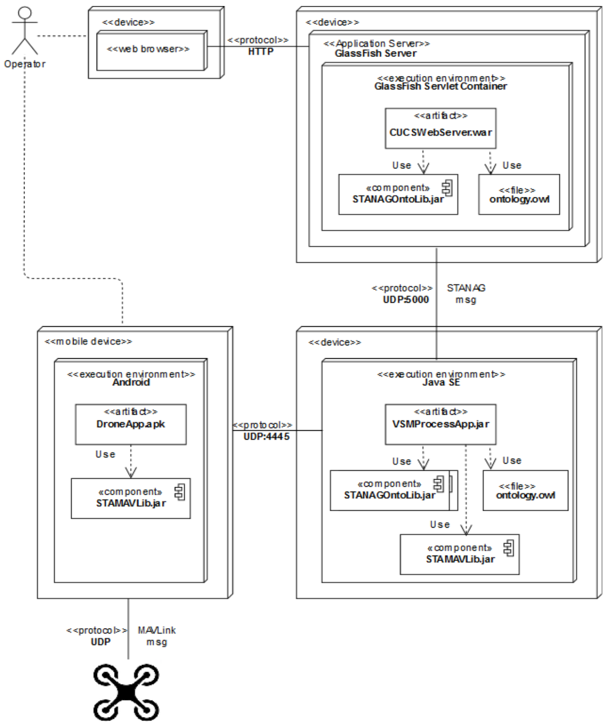
- An intermediate processing node for vehicle-specific operation
  - STANAG to MAVLink message translation
    - First-half matching – from a STANAG message to a STAMAVMessage object
- A Java UDP client/server
  - receives encoded STANAG messages
  - transmits vehicle-specific packets
- Integrates
  - STANAGOntoLib
  - STAMAVLib
- Overcomes compatibility problems of STANAGOntoLib's integration to an Android-based mobile device



System Components

STAMAVLib

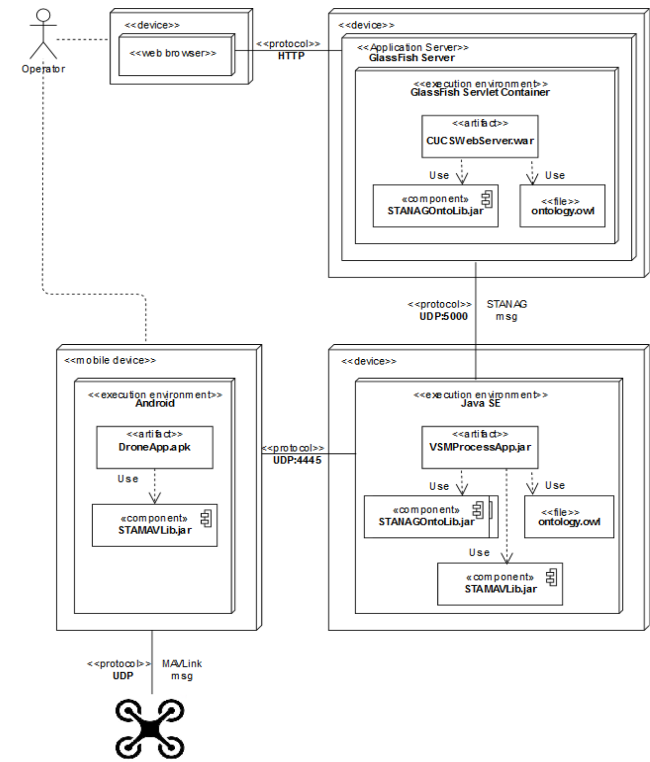
- A STANAG to MAVLink mapping library
  - definition of STAMAVMessage class
    - a common interface
    - implements Java Serializable class
  - a translation bridge from STANAG to MAVLink
    - binary data unit with control data of a STANAG message
- Translation issues:
  - not a 1 to 1 matching
  - different parameters for each protocol
  - much of STANAG information is redundant to MAVLink
- Enables communication



System Components

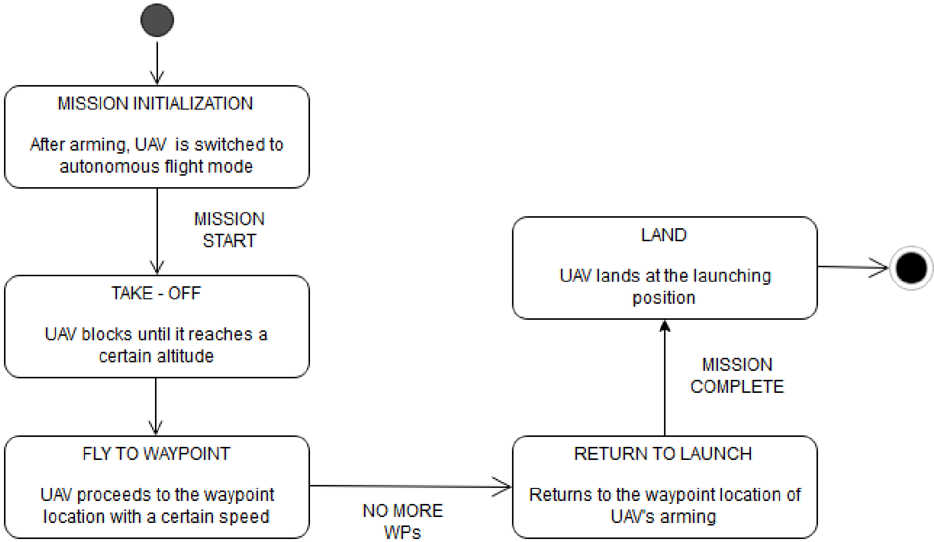
DroneApp

- An android application that acts as a hand-held mobile GCS
  - communicates with the UAV's autopilot
  - via MAVLink protocol
- Performs the "second half" of STAGAG to MAVLink translation
  - from a STAMAVMessage object to a MAVLink message
- An UDP server:
  1. receives serialized STAMAVMessage packets
  2. implements the matchings based on the type of serialized object
  3. generates the MAVLink messages and sends them to the UAV
- Integrates
  - STAMAVLib
  - DroneKit SDK
- DroneApp GCS implements Waypoint sub-protocol of MAVLink



Evaluation

- Simulation of a flight mission in which operator controls a quadcopter MAVLink protocol UAV by sending STANAG messages
  - using SITL simulator
  - MAVProxy



- A predefined flight scenario
  - based on the capabilities of implemented software

- Experimentations check system's:
  - proper functioning

- Positive flight tests validate system for:
  - feasibility
  - stability during protocol translation

Conclusion (1/2)

Contributions

- An ontology-based system by means of Semantic Web technologies
  - addresses the achievement of interoperability among UAVs
  - proposes an innovative approach to the development of a UCS
- ONTO_STANAG_4586 ontology
  - comprehensive representation model
    - consistent and logically sound based on reasoning tools applied
    - first attempt in recent research
  - applicable in the STANAG 4586 message communication
- STANAGOntoLib
  - an important asset for compliance with STANAG 4586
    - enables the ability of interpreting STANAG messages
    - increases semantic interoperability
    - integrable as external library

Conclusion (2/2)

Contributions (cont'd)

- Verification of STANAG 4586 practicability
  - achievable communication protocol, yet highly complex
    - heavily demanding in terms of compliance
    - strong investment
  - a network-enabled architecture without considering constraints in communication

Future Work

- Extension of ONTO_STANAG_4586 ontology with domain knowledge of existing ontologies
- Integration of the already implemented STANAG to MAVLink bridge
  - system performance improvement

Questions?

Thank you ☺