Background Introduction

- **Concept of Scenario**
  - Military/civilian naval/air/terrestrial scenarios
  - Battlefield, search and rescue of lost scouts/emergency responders, etc.
  - The entirety of the deployment connected via two or more redundant communication links
- **Available Links**
  - Satellites (Large latency, good availability, except for hostile jamming)
  - Remotely piloted aircrafts (Low latency, high mobility, intermittent, lossy link)

Problem Identification

- **Drawbacks of Single-path Communication**
  - Communication interruption
  - Long recovery time due to network outage
  - Manual intervention needed to recover
  - Hard management for network operators

- **Multiple Simultaneous Connections**
  - Aggregate bandwidth to gain higher throughput
  - Almost no-cost network handover
  - More reliable communication against link failure

Solution Design

- **Multi-path TCP**
  - Multiple interfaces with multiple connections
  - Simultaneously utilized to send data

- **Software-Defined Networking**
  - Separate the faulty/frail data plane from the robust network control plane
  - Network global view, centralized management and optimal performance

- **Architecture Overview**
  - MPTCP is enabled at
    - Each Host
    - Each End User
  - SDN-enabled switch/router at
    - Each SATCOM
    - Each aircraft
  - Centralized SDN controller
    - Connects every SDN-enabled switch
    - Runs Multi-commodity Flow (FDM-based) traffic manager
    - Periodically collects network stats from SDN-enabled switches
    - Calculates dynamic traffic flow allocation for every user based on their priorities

- **FDM-based traffic optimizer module**
  - Problem formulated as an Multi-Commodity Flow problem
  - Solve with the Flow Deviation Method (FDM)
  - Dynamically updates traffic flow allocation when the topology and traffic change

Emulation Environment

- **Implementation Detail**
  - Process-based nodes
    - Hosts
    - Stations
  - MPTCP enabled on every host and station with Linux kernel implementation
  - Traffic Control link
    - Bandwidth
    - Delay
    - Mobility is supported
    - SDN controller
      - OpenFlow API
      - Flow table
      - Decides routing
      - OVS queue
      - Restricts bandwidth
    - FDM module
      - Python implementation
      - Traffic generator:
        - D-ITG (custom rate)
        - iPerf (max rate)
      - Capture packets with Wireshark at any interfaces

Preliminary Evaluation

- **Mininet-WiFi Testbed**
  - One wireless AP as Aircraft
  - One Open vSwitch as SATCOM
  - One host node as ship
  - Two terrestrial nodes as users
  - Ethernet emulates SATCOM link
  - 802.11g emulates Aircraft link

- **Network configuration**
  - SATCOM backhaul network
    - 50Mbps and 250ms
  - Aircraft backhaul network
    - 1Mbps and 10ms
  - User demand: 3Mbps
  - Users randomly move near AP