

Resilient & Reconfigurable Maritime COMMS

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PRESENTATION AGENDA

Background & Motivation

Maritime Communication Challenges

Role of SDR and SDN

Proposed SDN–SDR Framework

Use Case & Performance Insights

Security Considerations

Conclusions & Future Work

RESEARCH QUESTION

Is a cross-layer SDR/SDN COMMS integration with existing SATCOM infrastructure feasible and practical?

Can the new framework ameliorate the resilience, performance, and security of resource-constrained maritime COMMS and networks?

BACKGROUND & MOTIVATION

Maritime industry is vital to global trade and safety

Modernization with technologies like IoT, UAVs, AUVs, IoS

Need for secure, high-bandwidth, and flexible COMMS

Traditional systems have limitations offshore

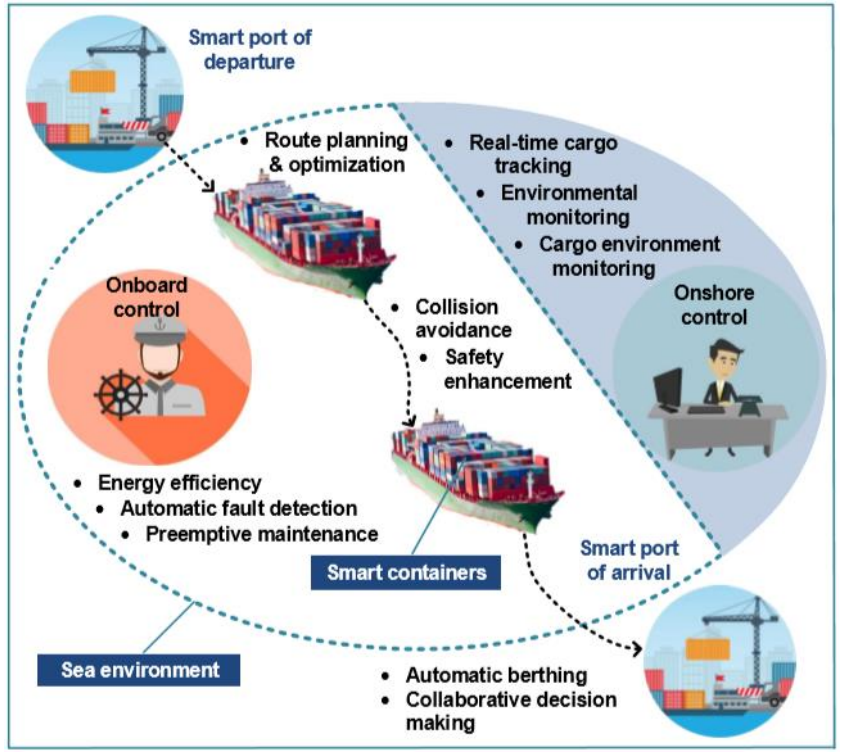


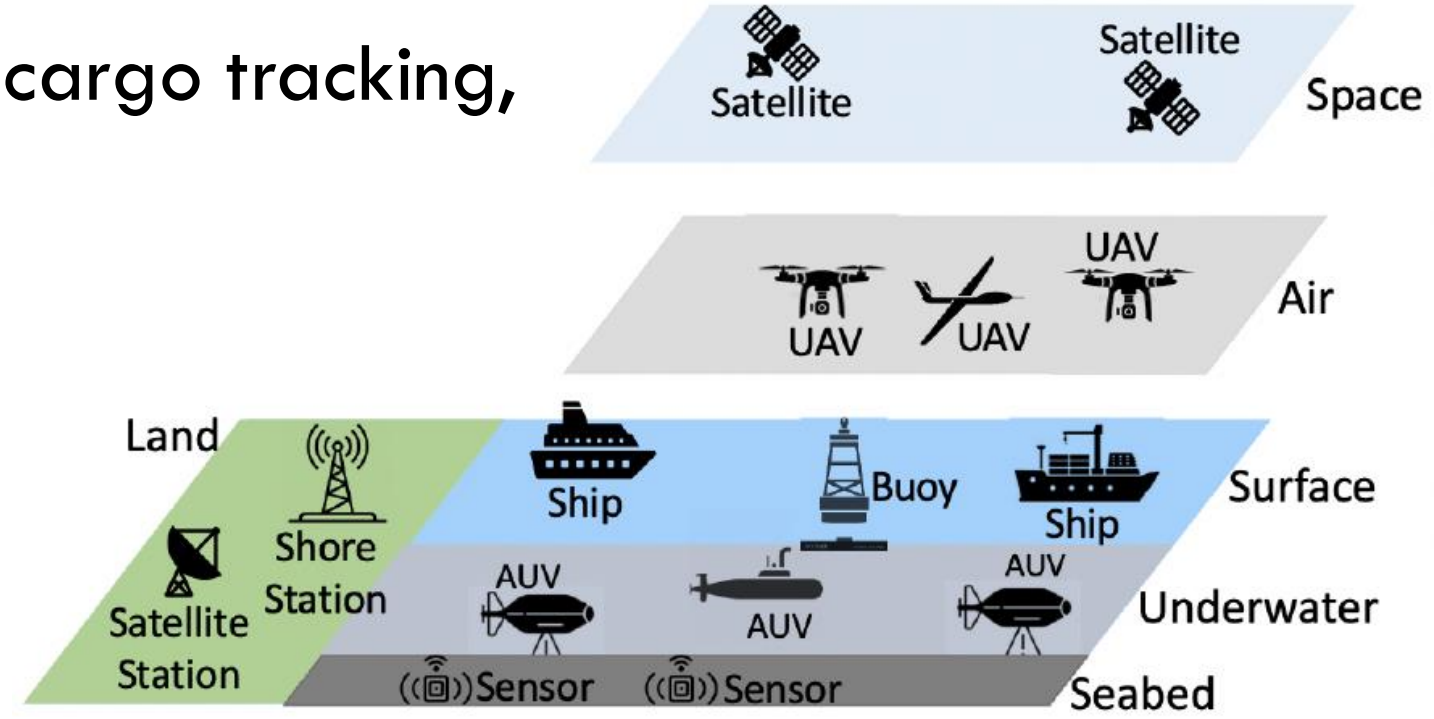
Figure 1. Key emerging applications of IoS [2]

EXISTING MARITIME COMMS ENVIRONMENT

Platforms: Land, Water, Air, Space

Technologies: VHF, AIS, SATCOM, Wi-Fi

Applications: Navigation, cargo tracking, fleet management



KEY MARITIME COMMS CHALLENGES

Maritime industry faces three significant COMMS hurdles

- Limited **range** offshore (Wi-Fi, Cellular)
- **High latency** in SATCOM
- **High data demand–**IoT, sensors, recreation

MARITIME—GROWING SECURITY THREAT

Maritime sector lacks standardized cybersecurity strategy

Increasingly complex and vulnerable automated ship systems

Nine-fold increase in cyber-attacks on shore-based maritime systems

KEY VULNERABILITIES

AIS: No Authentication

→ Fake msg & false man-in-the-water sig

GPS: Signal Spoofing

→ Reroutes vessels without an alarm

VSAT: Lacks Authentication & Encryption

→ Vulnerable at the implementation level

ECDIS: Insecure Updates (Internet/USB)

→ Exposes sys. to security risks



SDR (SOFTWARE DEFINED RADIO)
FLEXIBLE RADIO



WHAT IS AN SDR?

Radio system where signal processing is done via software, not fixed hardware

Reconfigurable platform — supports multiple radio standards (e.g., FM, GPS, AIS, LTE, 5G)

Core radio functions–modulation, demodulation, filtering–handled by software

Software runs on general-purpose (PC/laptop) or programmable hardware (FPGA/SoC)

KEY SDR ADVANTAGES

Multi-standard support

Adaptive performance

Fast development

Flexible operation

MARITIME SDR APPLICATIONS

Cost-effective systems

- Build low-cost Tx for AIS and VDES.

Enhanced functionality

- Support features like voice-to-text and SMS-style messaging.

Streamlined infrastructure

- Eliminate need for multiple phy devices for different COMMS tasks
- Simplify maintenance with reduced hardware footprint



SDN (SOFTWARE DEFINED NETWORK) INTELLIGENT NETWORKS



WHAT IS AN SDN?

Decouples network's control plane (decision-making) from data plane (traffic forwarding)

Provides centralized, programmable network control

Simplifies complex network configurations

KEY SDN ADVANTAGES

Centralized Control

Programmable (e.g., traffic optimization, intelligent routing)

Flexible and Scalable

Remote Management

Fine-grained security

MARITIME SDN APPLICATIONS (SECURITY ENHANCEMENTS)

Monitoring Controller – Analyzes device data

Detection Engine – Identifies threats

Mitigation Engine – Reroutes and isolates threats

PROPOSED SOLUTION: AN SDN-SDR FRAMEWORK

Goal: Alleviate network and physical layer complexities in dynamic maritime environments

Three Planes
Service, Controller, Resource

Proposal: A Unified SDN-SDR framework integrated with existing SATCOM infrastructure

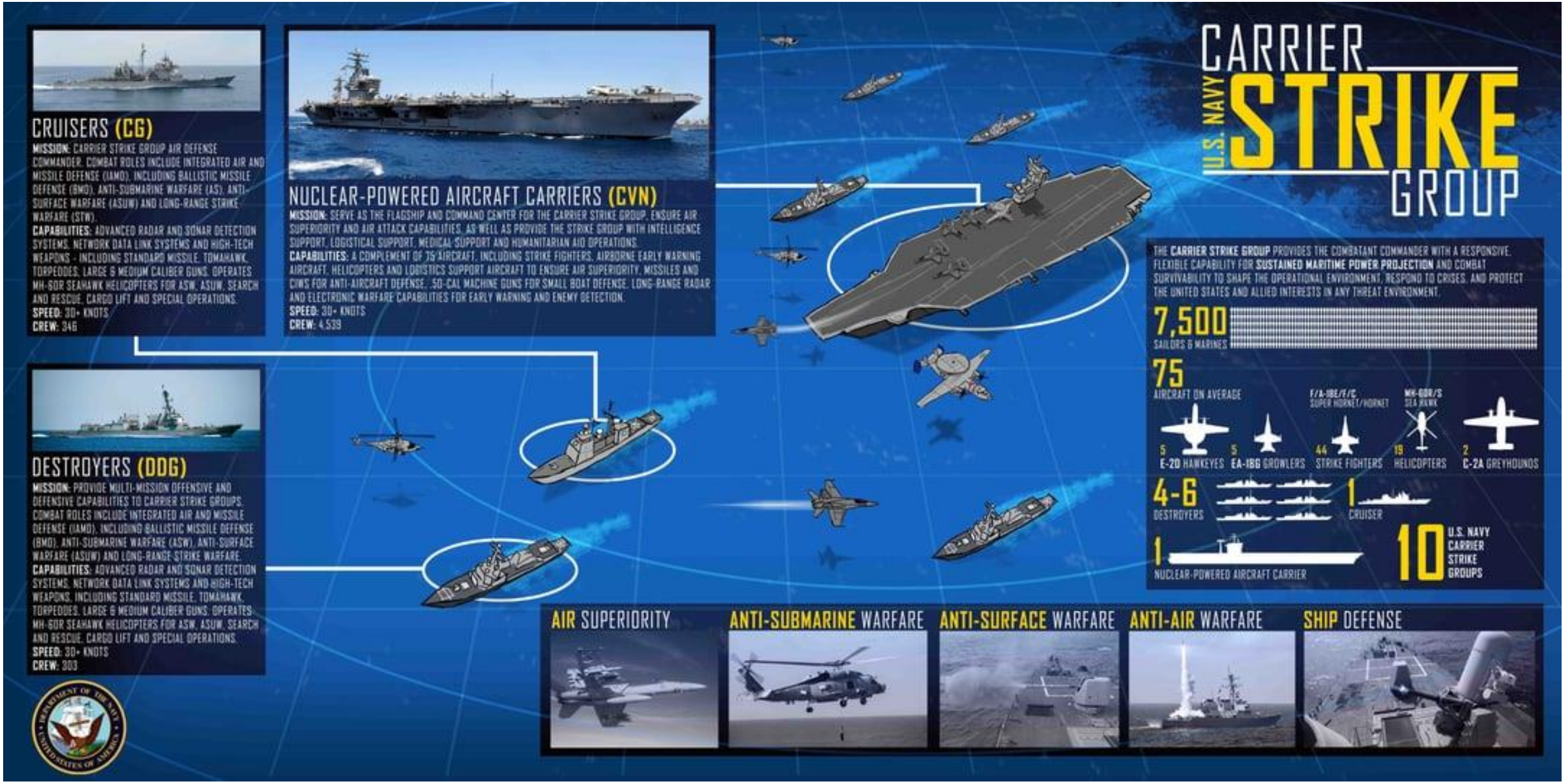
Combines
SDR, SDN, & SATCOM

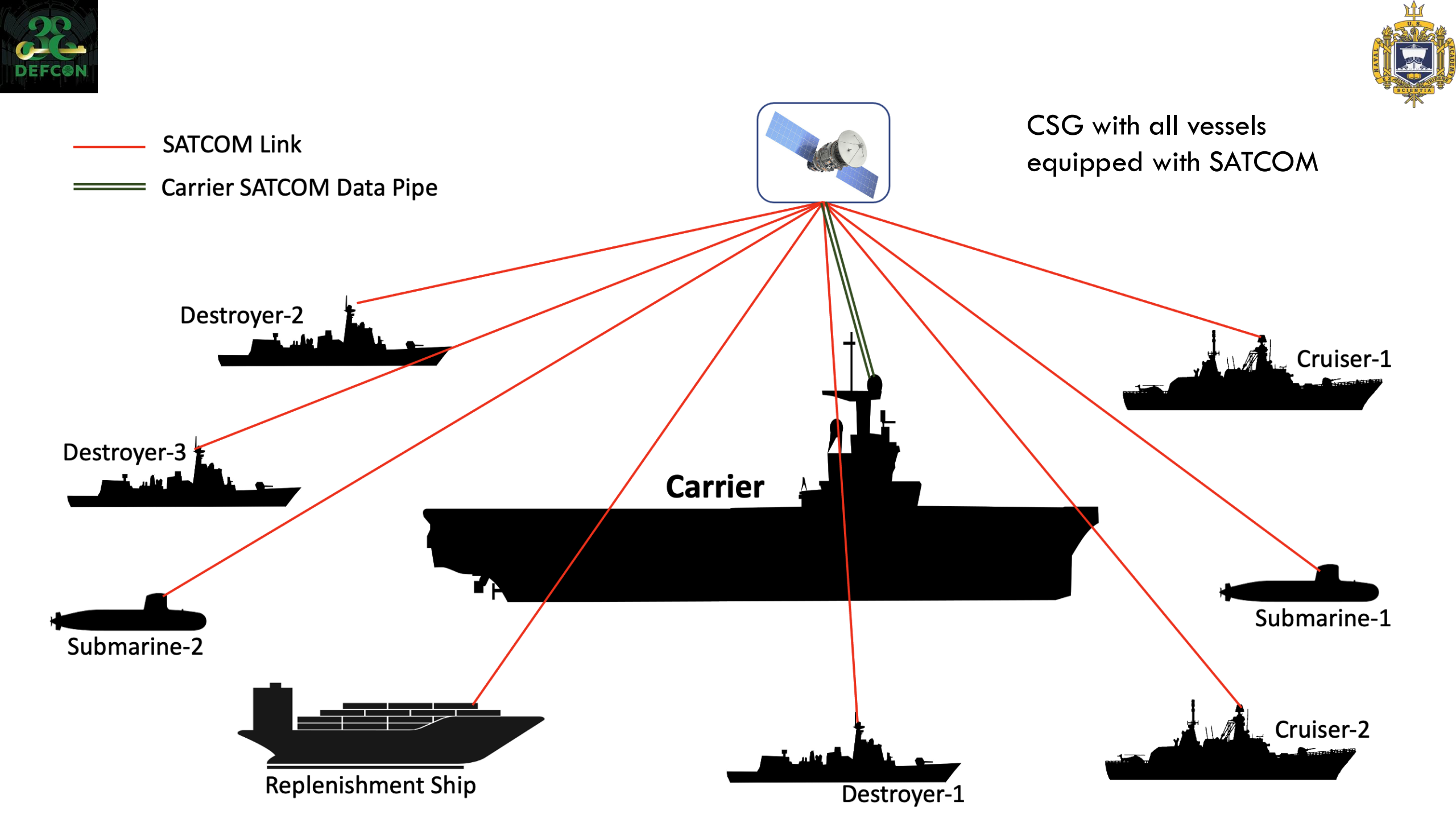
Outcome: Simplified onboard infrastructure with easier mgmt. and maintenance

Flexible COMMS
V2V and V2Carrier

USE CASE: A NAVY CARRIER STRIKE GROUP (CSG)

In a CSG, smaller ships (e.g., Destroyers) have limited SATCOM bandwidth (256-512 Kbps), while large ships (Carriers) have high-capacity links (4-8 Mbps).


CRUISERS (CG)
MISSION: CARRIER STRIKE GROUP AIR DEFENSE COMMANDER. COMBAT ROLES INCLUDE INTEGRATED AIR AND MISSILE DEFENSE (IAMD), INCLUDING BALLISTIC MISSILE DEFENSE (BMD), ANTI-SUBMARINE WARFARE (AS), ANTI-SURFACE WARFARE (ASUW) AND LONG-RANGE STRIKE WARFARE (STW).
CAPABILITIES: ADVANCED RADAR AND SONAR DETECTION SYSTEMS, NETWORK DATA LINK SYSTEMS AND HIGH-TECH WEAPONS - INCLUDING STANDARD MISSILE, TOMAHAWK, TORPEDOES; LARGE & MEDIUM CALIBER GUNS. OPERATES MH-60R SEAHAWK HELICOPTERS FOR ASW, ASUW, SEARCH AND RESCUE, CARGO LIFT AND SPECIAL OPERATIONS.
SPEED: 30+ KNOTS
CREW: 346
NUCLEAR-POWERED AIRCRAFT CARRIERS (CVN)
MISSION: SERVE AS THE FLAGSHIP AND COMMAND CENTER FOR THE CARRIER STRIKE GROUP, ENSURE AIR SUPERIORITY AND AIR ATTACK CAPABILITIES, AS WELL AS PROVIDE THE STRIKE GROUP WITH INTELLIGENCE SUPPORT, LOGISTICAL SUPPORT, MEDICAL SUPPORT AND HUMANITARIAN AID OPERATIONS.
CAPABILITIES: A COMPLEMENT OF 75 AIRCRAFT, INCLUDING STRIKE FIGHTERS, AIRBORNE EARLY WARNING AIRCRAFT, HELICOPTERS AND LOGISTICS SUPPORT AIRCRAFT TO ENSURE AIR SUPERIORITY, MISSILES AND CIWS FOR ANTI-AIRCRAFT DEFENSE, .50-CAL MACHINE GUNS FOR SMALL BOAT DEFENSE, LONG-RANGE RADAR AND ELECTRONIC WARFARE CAPABILITIES FOR EARLY WARNING AND ENEMY DETECTION.
SPEED: 30+ KNOTS
CREW: 4,539
DESTROYERS (DDG)
MISSION: PROVIDE MULTI-MISSION OFFENSIVE AND DEFENSIVE CAPABILITIES TO CARRIER STRIKE GROUPS. COMBAT ROLES INCLUDE INTEGRATED AIR AND MISSILE DEFENSE (IAMD), INCLUDING BALLISTIC MISSILE DEFENSE (BMD), ANTI-SUBMARINE WARFARE (ASW), ANTI-SURFACE WARFARE (ASUW) AND LONG-RANGE STRIKE WARFARE.
CAPABILITIES: ADVANCED RADAR AND SONAR DETECTION SYSTEMS, NETWORK DATA LINK SYSTEMS AND HIGH-TECH WEAPONS, INCLUDING STANDARD MISSILE, TOMAHAWK, TORPEDOES; LARGE & MEDIUM CALIBER GUNS. OPERATES MH-60R SEAHAWK HELICOPTERS FOR ASW, ASUW, SEARCH AND RESCUE, CARGO LIFT AND SPECIAL OPERATIONS.
SPEED: 30+ KNOTS
CREW: 303
U.S. NAVY
CARRIER STRIKE GROUP
THE CARRIER STRIKE GROUP PROVIDES THE COMBATANT COMMANDER WITH A RESPONSIVE, FLEXIBLE CAPABILITY FOR SUSTAINED MARITIME POWER PROJECTION AND COMBAT SURVIVABILITY TO SHAPE THE OPERATIONAL ENVIRONMENT, RESPOND TO CRISES, AND PROTECT THE UNITED STATES AND ALLIED INTERESTS IN ANY THREAT ENVIRONMENT.
7,500
SAILORS & MARINES
75
AIRCRAFT ON AVERAGE
F/A-18E/F/G SUPER HORNET/HORNET
MH-60R/S SEA HAWK
5 E-2D HAWKEYES
5 EA-18G GROWLERS
44 STRIKE FIGHTERS
19 HELICOPTERS
2 C-2A GREYHOUNDS
4-6
DESTROYERS
1
CRUISER
1
NUCLEAR-POWERED AIRCRAFT CARRIER
10
U.S. NAVY CARRIER STRIKE GROUPS
AIR SUPERIORITY
ANTI-SUBMARINE WARFARE
ANTI-SURFACE WARFARE
ANTI-AIR WARFARE
SHIP DEFENSE

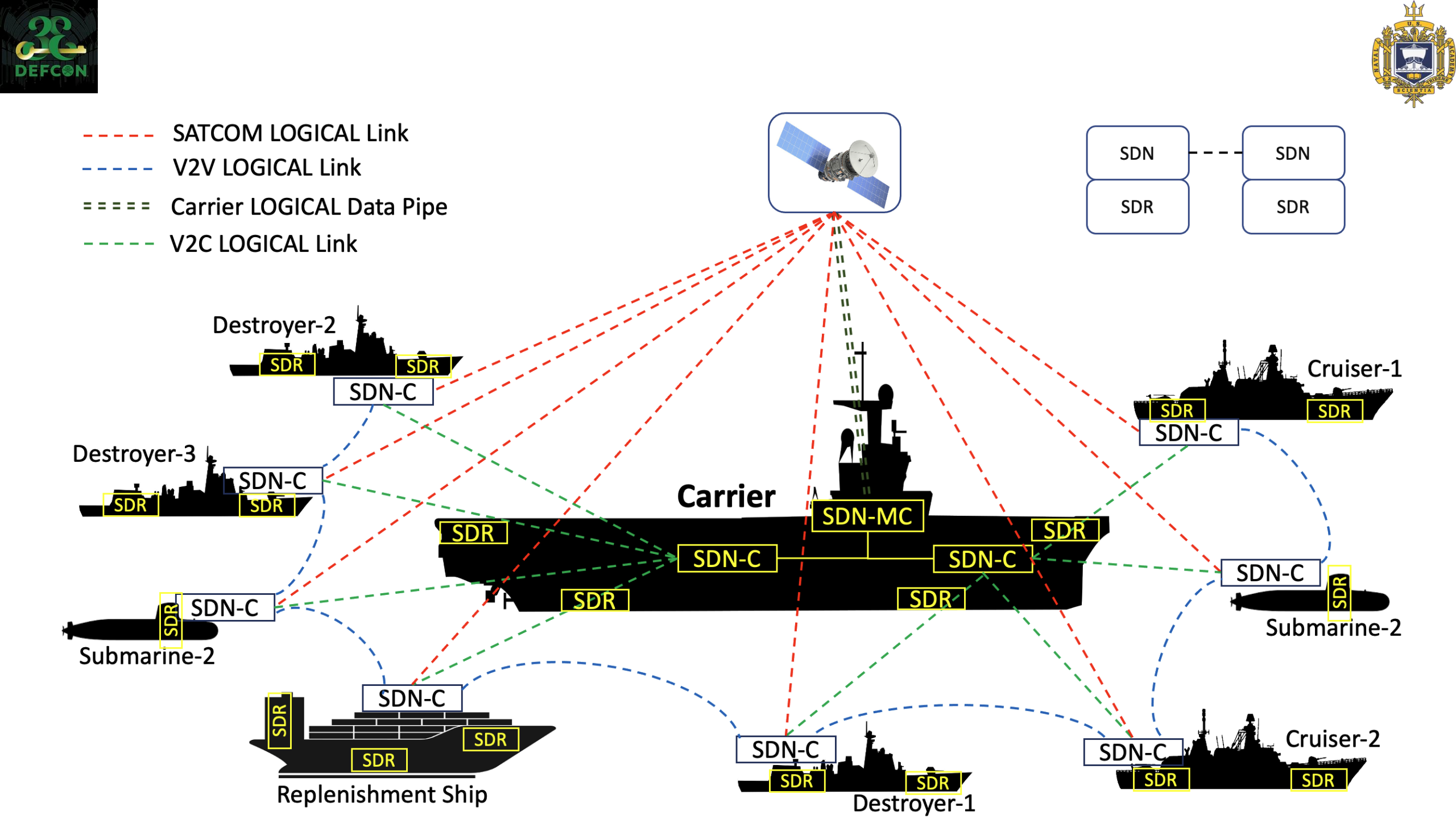

SATCOM Link
Carrier SATCOM Data Pipe
CSG with all vessels equipped with SATCOM
Destroyer-2
Destroyer-3
Submarine-2
Carrier
Cruiser-1
Submarine-1
Replenishment Ship
Destroyer-1
Cruiser-2

CSG COMMS—PROPOSED SOLUTION

Small ships don't need to make slow, direct SATCOM requests.

Use a fast, line-of-sight (LOS) SDN-SDR link to connect to the Carrier.

Carrier uses its high-bandwidth data pipe to fulfill the request


SATCOM LOGICAL Link
V2V LOGICAL Link
Carrier LOGICAL Data Pipe
V2C LOGICAL Link
SDN
SDR
SDN
SDR
Destroyer-2
SDR
SDR
SDN-C
Destroyer-3
SDN-C
SDR
SDR
Cruiser-1
SDR
SDR
SDN-C
Carrier
SDN-MC
SDR
SDR
SDN-C
SDN-C
SDR
SDR
SDN-C
SDR
Submarine-2
SDN-C
SDR
Submarine-2
SDN-C
SDR
SDR
SDR
Replenishment Ship
SDN-C
SDR
SDR
Destroyer-1
SDN-C
SDR
Cruiser-2
SDR
SDR

PERFORMANCE GAINS (IN THEORY)

Avoids high-latency SATCOM links for intra-group COMMS

Boosts performance through low-delay SDN–SDR links

Propagation Delay Comparison:

- SATCOM (Geosynchronous): A round-trip takes ~552 ms.
- SDN-SDR (LOS at 25km): A round-trip takes ~0.17 ms.

Carrier's higher bandwidth greatly accelerates requests

SDN–SDR link adds minimal delay, even with extra hop

CACHING FOR FURTHER EFFICIENCY

Carrier caches previously accessed data locally

Other vessels can retrieve it without using SATCOM

Reduces cost, latency, and satellite bandwidth usage

CONCLUDING REMARKS

Current maritime COMMS are limited in performance and security

SDN–SDR framework provides a flexible, resilient solution via SATCOM integration

Demonstrated performance gains (in theory) in CSG use case

Enables smarter, data-driven maritime operations through digital transformation

FUTURE WORK

Phase 1: A simulation-based implementation of the framework to test it against various environmental factors and satellite types (LEO, MEO, GEO).

Phase 2: Implement a working prototype testbed using commercial off-the-shelf (COTS) SDN and SDR hardware.

CITATION

Niknami, Nadia, **Avinash Srinivasan**, Ken St. Germain, and Jie Wu. 2023. "Maritime Communications—Current State and the Future Potential with SDN and SDR" *Network* 3, no. 4: 563-584. https://doi.org/10.3390/network3040025

Thank you!!!

We are happy to take questions



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