Complex Networks and Systems

Dr Robert J. Bonneau
Program Manager
AFOSR/RSL
Air Force Research Laboratory
Complex networks uses the results of the mathematical quantification of critical information delivery to assure, manage, predict, and design Air Force networks

*Local Network Research:* Coding that assures information delivery and security
*Network Management Research:* Network protocol to maximize information flow
*Global Network Research:* Predict network performance and design robustness

**Dynamic, Heterogeneous, Air Force Network**

- **Raw Network Data**
- **Guaranteed Delivery Of Time Critical Information**
- **Mathematical Characterization of Network**
- **Unified Mission Assured Design**
- **Local Network Research* Assure Critical Information Delivery**
- **Network Management Research* Manage Information Flow**
- **Diverse Types of Networks (Fundamental Principles)**
- **Communications Networks**
• Current networks are managed with multiple protocols depending on their taxonomy
• Air Force networks, particularly Airborne Networks are heterogeneous
• A unified network approach should adapt to the conditions and provide design principles

Current Networks

- Deterministic
- Hybrid
- Random

Stable Under Some Conditions

Less: Disruption Tolerant, Latency
More: Information Loss Under Interference, Observable/Controllable

Future Networks

Less: Information Loss Under Interference, Observable/Controllable
More: Disruption Tolerant, Latency

Design Principles According To Constraints

Adapt According To Measurements
Units of information transfer do not have to be packets – generalizing this approach to other scientific areas allows generalized network design and analysis within constraints.

- Taking this approach can lead to an integrated strategy of stable design formulation.
Comprehensive Systems Modeling

- **Model** heterogeneous distributed systems using unified, modular, composable and scalable mathematical framework from previous measurement and system specification
  - Use new statistical, algebraic, and geometric representations and theory for modularized representations and composable into a modeling framework

![Diagram](image-url)
Measurement-Based System Verification

- Verify the properties of a given unified system through measurement of a limited set of parameters and calculate system risk of not meeting mission requirements
  - Assess risk by distance between properties of desired representation (model) and measured properties
  - Incorporate risk of sparse measurement

Mission Requirements

Desired Properties

Performance Verification

**Risk Assessment**

**Measurement**

**Desirable Properties:**
(Example) Robustness to Disruption

**Undesirable Properties:**
(Examples) Latency, Interference, Computational Overhead

**Measured Properties**
- Define general application architectural and policy design principles through unified assessment of system operating risk
  - Apply to existing architectures through policy implementation

**System Operating Trade-space**

**Architecturally Included Modalities**
*(low mission risk)*

**Architecturally Excluded Modalities**
*(high mission risk)*
- Measure and Model, for Design using a comprehensive, modular, compositional, and scalable framework
  - Models inform measurement based verification of system properties
  - Strategy enables designs to quantifiably meet mission performance objectives in heterogeneous dynamic systems