



Integrated Network for China Aeronautical Communications

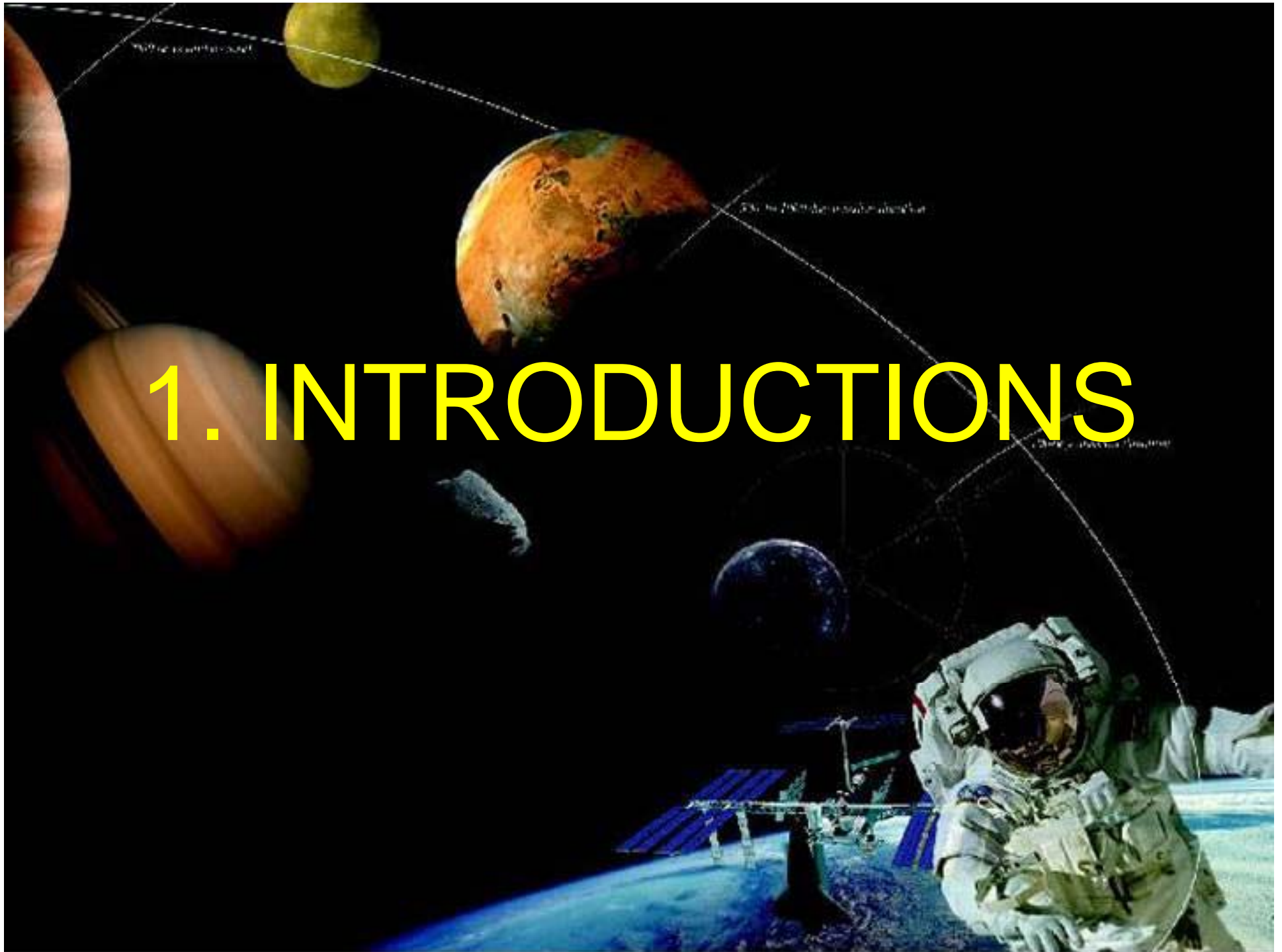
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Bing DU

Content

- ◆ Introductions
- ◆ Modeling of Integrated Network
- ◆ Information Compression and Reconstruction
- ◆ Cooperative Communications in Aeronautical Communications
- ◆ Gateway Cluster in China

1. INTRODUCTIONS



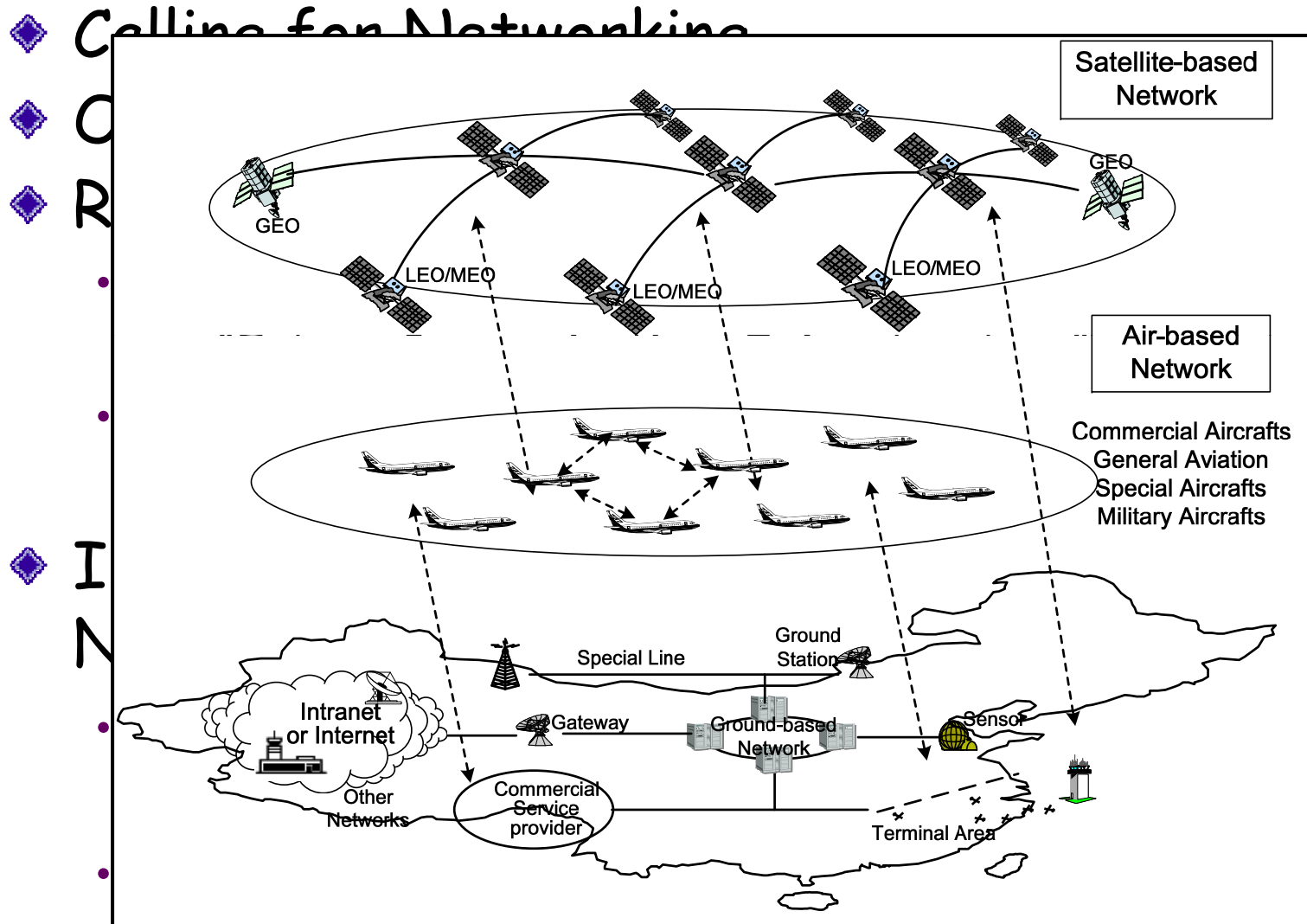
Background

- ◆ Air transportation is taking the 40 percentage of the whole traveling and trading worldwide.
 - ATM, ATC Communications
 - AOC, APC Communications
- ◆ Characteristics of Aeronautic communications
 - Frequency bandwidth scarce
 - Power Constraints
 - Dynamic topology

The capacity of the existing ATC/ATM communication infrastructure has already strongly saturated

Background

Celling for Networking



- Corresponding Ground facilities

Thus ...

- ◆ establish heterogeneous networks for aeronautical communications
- ◆ capable of integrating different communication systems as well as different applications into a single global aeronautical network
- ◆ sub-networks
 - Space
 - Airborne

It will be impractical to apply the same technologies used in terrestrial networks.

2. Modeling of Integrated Network

The background image is a composite of several elements. At the top, a network diagram with white nodes and connecting lines is superimposed over a dark space background. Below this, various celestial bodies are shown: Earth in the upper center, Mars to its right, and the gas giants Jupiter, Saturn, Uranus, and Neptune in a diagonal line from the middle left towards the bottom right. In the bottom right corner, an astronaut in a white space suit is visible, floating in space. The overall scene suggests a global or interplanetary network.

1. Modeling of Integrated Network

- ◆ Aviation information service
 - "Network-Centric" perspective
 - to provide anytime, anywhere cooperative air traffic state information for all aviation concerned departments.
- ◆ Integrate **available communications** to optimize the system for better applications
- ◆ must be
 - Heterogeneous and capacity-approaching
 - With flexibility to appropriate for the dynamic topology communications
 - Different from existing network architectures

1. Modeling of Integrated Network

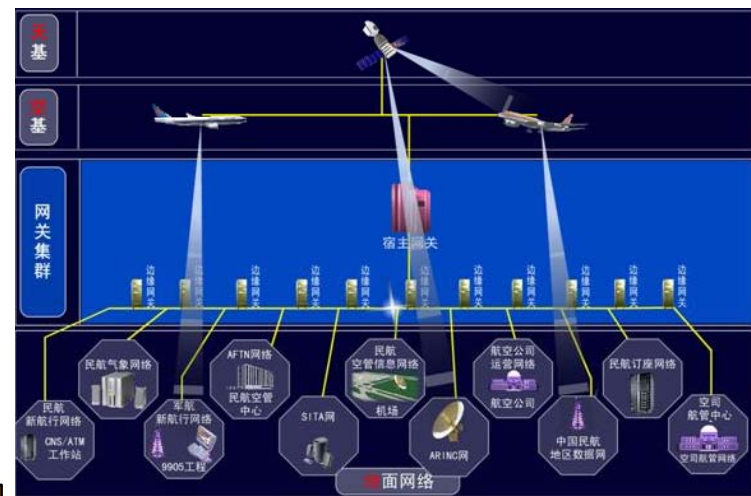
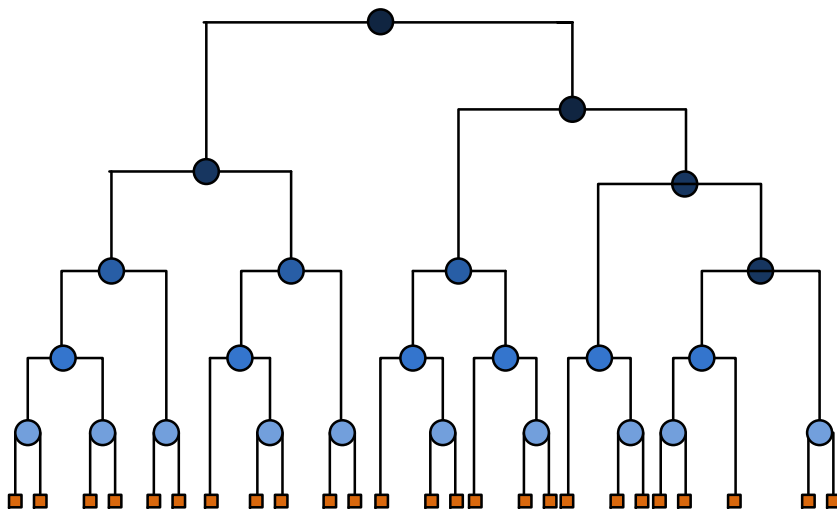
- ◆ "Virtual Structure"
 - from physical-layer to application-layer
 - make it customer-built to the missions.
- ◆ Integrate heterogeneous networks
- ◆ Optimize resource allocation
- ◆ Provide a highly consistent and available information platform to the aviations

1. Modeling of Integrated Network

- ◆ Such integrated networks often exhibit **hierarchical organization**
 - vertices divide into groups
 - further subdivide into groups of groups
 - so forth over multiple scales
- ◆ Each groups
 - corresponding to the **same functional unit**
 - relatively an independent individual
 - has autonomy to manage its representative and behavior.

1. Modeling of Integrated Network

- ◆ Hierarchical structure is represented by **a tree**
- ◆ Closely related pairs of vertices have lowest common ancestors that are lower in the tree than those of more distantly related pairs.



1. Modeling of Integrated Network

- ◆ Monte-Carlo simulations
 - sample the network data in the space of all possible tree structures
- ◆ Each node obtains a probability
 - describe the possibility of the node connection with other branch nodes
- ◆ Capturing behavior of network topology
 - Pr Decrease as we move higher up the tree.
 - Clustering
 - Pr Increases as we move down the tree.
 - Assorting

1. Modeling of Integrated Network

- ◆ A consensus structure
 - captures the topological features that appear consistently across all of the trees
 - typically is a better summary of the network's structure than any individual tree
- ◆ By a dual thought, can we integrate heterogeneous network by a tree structure?
 - "Gateway Cluster" Structure

Network topology is generated in a statistical way, which fits the variations of aeronautical communications
Providing a model for simulations and analysis.

3. Information Compression and Reconstruction

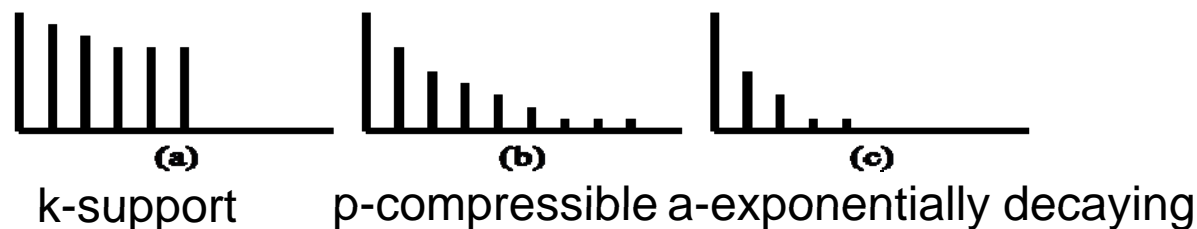


3.Information Compression and Reconstruction

- ◆ After combining the existing networks, there will be **a surge of data** in the network flow.
- ◆ facing “lots of data contain no information”
- ◆ Information about targets will be gathered by fusing data from different nodes in the network
- ◆ Compressed sensing : Network data.

3.Information Compression and Reconstruction

- ◆ a small collection of linear projections of a sparse signal contains enough information for reconstruction in proper basis representations
 - discrete cosine transform (DCT)
 - a discrete wavelet transform (DWT)
 - Fourier transform



3.Information Compression and Reconstruction

- ◆ Compressed Network data

- research is far from complete

- ◆ Based on Graphic way

- Graphic way describing network
- vertices of the graph represent the nodes of the network
- edges between vertices represent the links between the nodes with its adjacent nodes.

We can borrow the graphic way to implement spatial compression of the network data.

3.Information Compression and Reconstruction

- ◆ Tree-like structure
 - Clustering and grouping
- ◆ Each group can be a unit for compression
- ◆ Graph wavelet
 - extends the traditional wavelet transform
 - applied to data elements connected via an arbitrary graph topology.
- ◆ wavelets are applied to the spatial domain rather than the temporal domain.
- ◆ transformed by graph wavelet, network data is sparse with graph wavelet coefficients considering the traffic pattern in the topology

3.Information Compression and Reconstruction

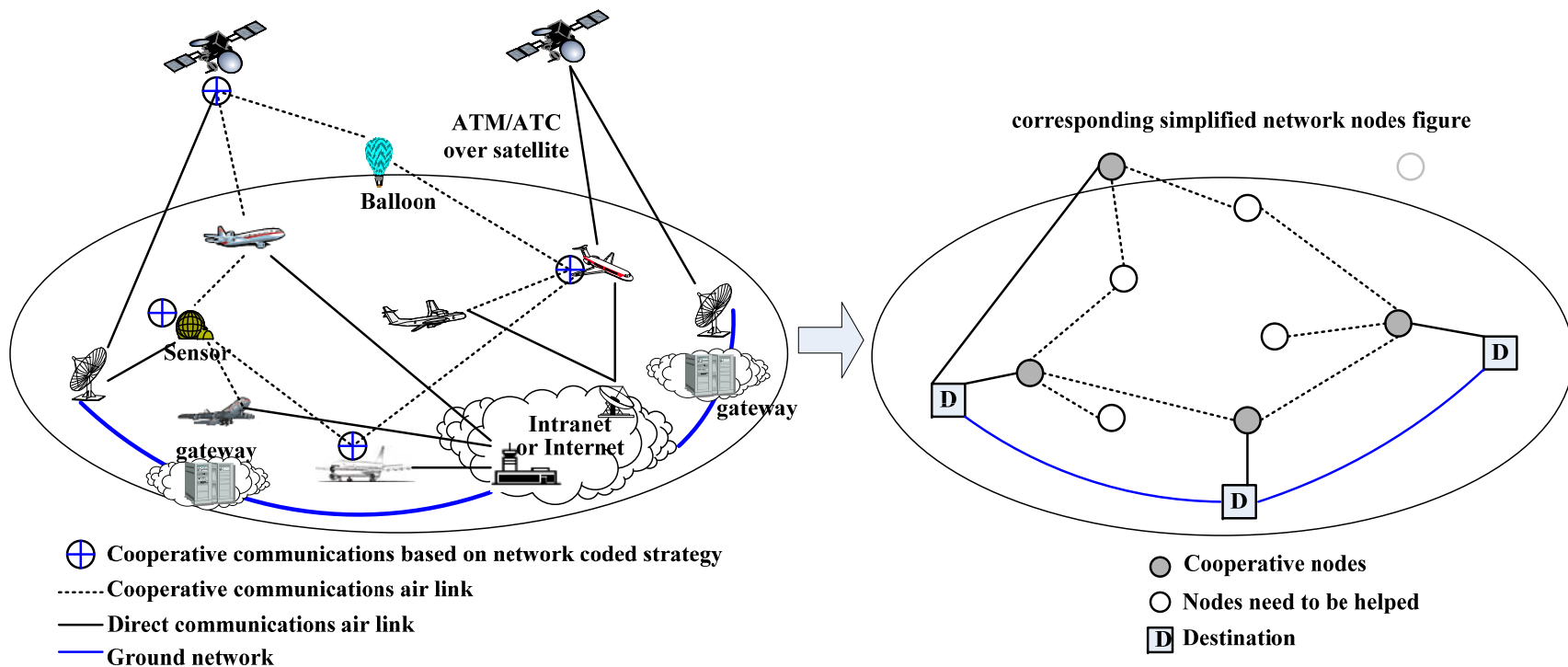
- ◆ each node in the sub-network encodes its data with a random projection matrix , generated by a pseudo-random number generator seeded with its identifier, as MAC address .
 - Data: $x_j \in R^N$
 - Random projection Matrix $\mathbf{A}_j \in R^{K \times N}$
 - Compression $y_j = \mathbf{A}_j x_j, y_j \in R^K \quad K \ll N$
- ◆ Especially, when a sub-network exchanges data with another sub-network, the compressed data puts up its superiority with less processing complexity and great capacity for information-valued data.

4. Cooperative Communications in Aeronautical Communications



4. Cooperative Communications

◆ The resource of frequency and power is precious for the aeronautical communications



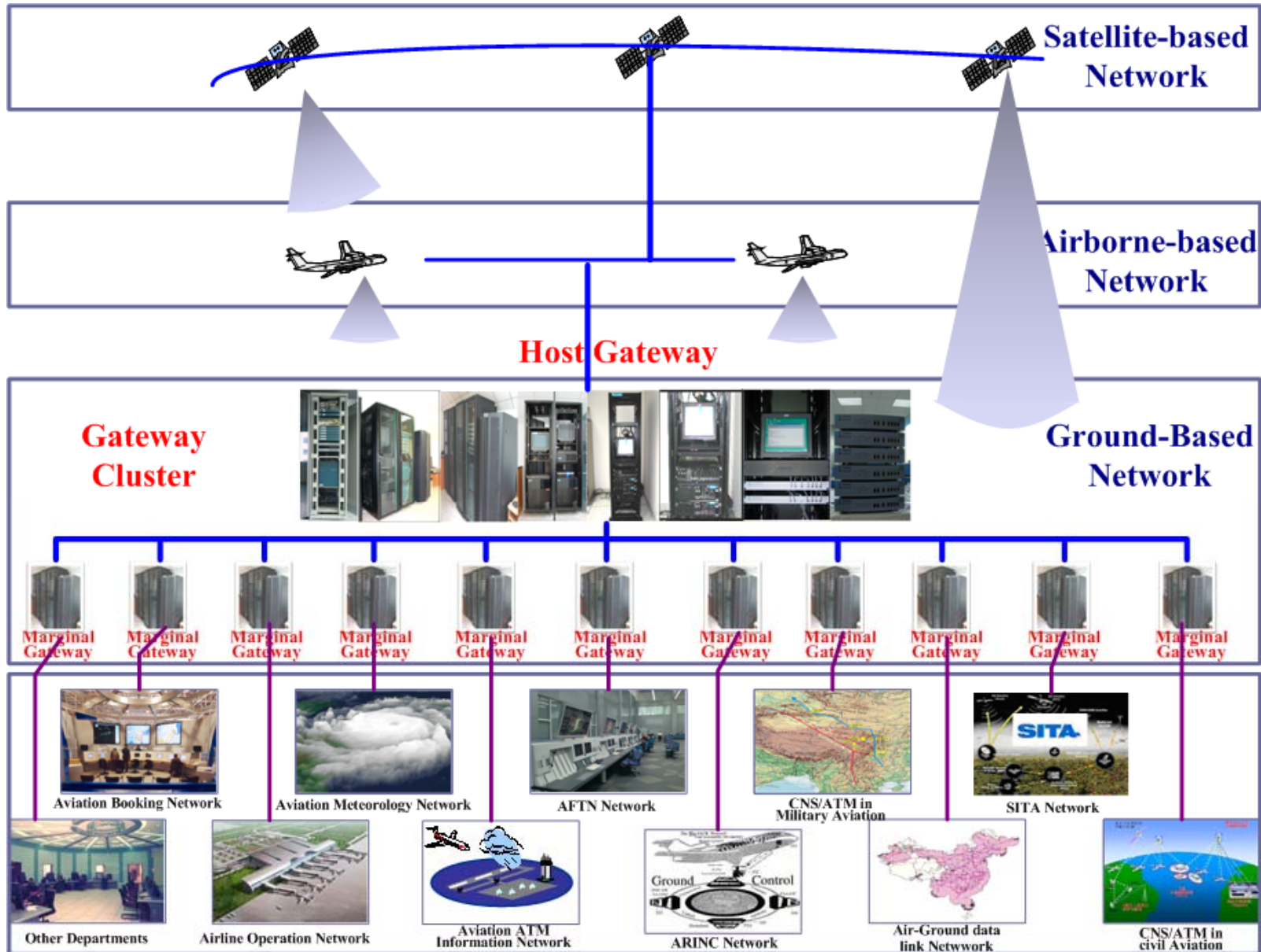
4. Cooperative Communications

- ◆ Cooperative protocol
- ◆ Network-coding
 - Bit-level: network layer, bit combination
 - Signal-level: physical-layer, analog signal combination
- ◆ Relay selections
 - Based on outage probability
 - Dynamic topology
- ◆ Channel state information estimation
- ◆ Game theory

5. Gateway Cluster in China



Gateway Cluster System



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Protocols in Gateway

- ◆ Transmission protocols
 - Defines the management and routing protocols to make sure normal running of the system
- ◆ Link control protocols
 - State information of transmission to ensure the reliable connection and delivering.
- ◆ Routing
 - Centralized-routing
 - Avoid the excess complex routing, for its massive information flow.
 - Centralized routing mode is selected to keep the simplicity of the computation

Protocols in Gateway

◆ Management

- distributed, intelligent, and extensible functions
- Charging
- Malfunction detection
- Performance monitoring
- Configuration
- Security

Design of gateway cluster

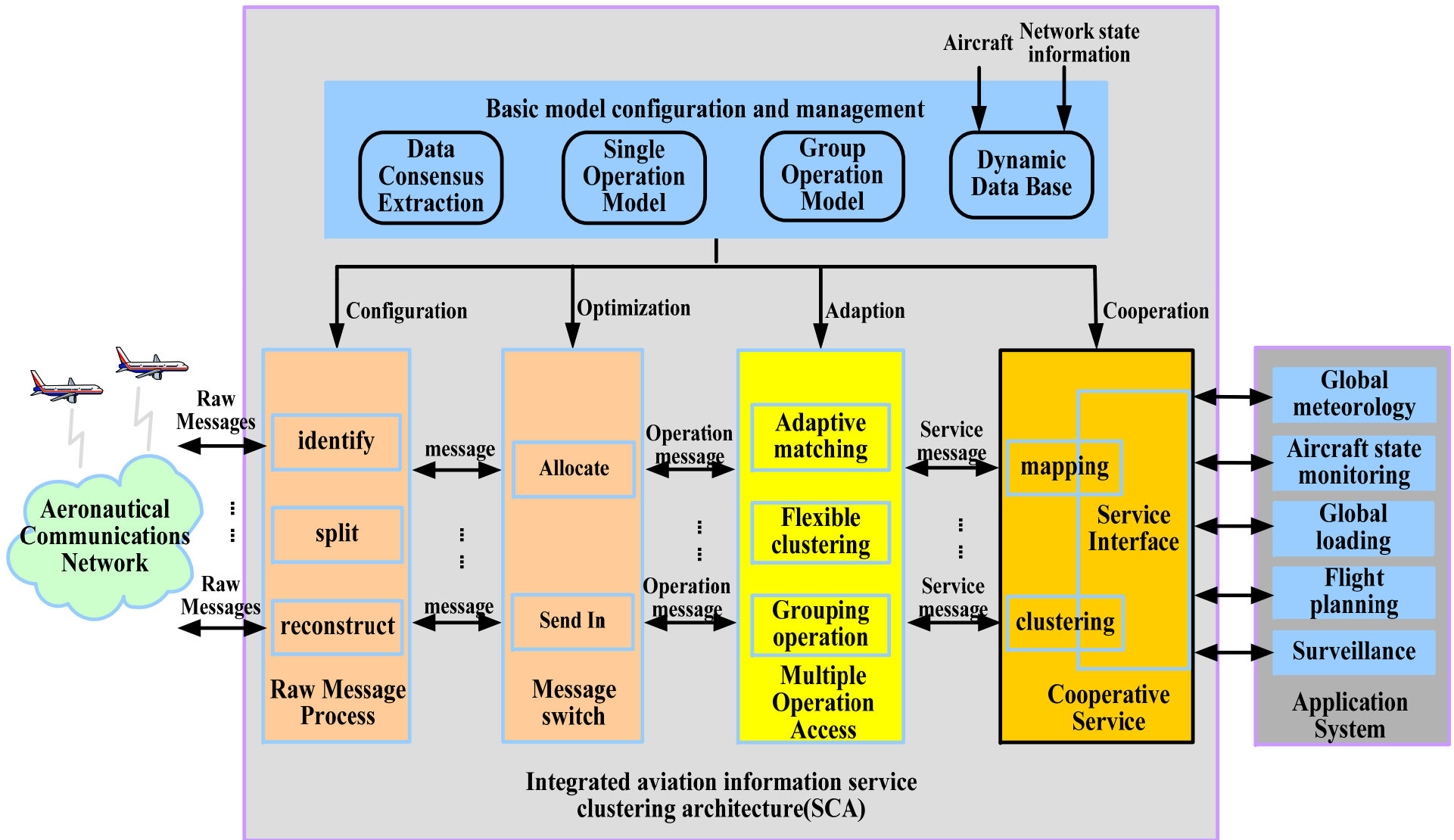
- ◆ Separation of communications module from control module
- ◆ Commun. M.: designed in a general way
 - All the communication modules do the jobs related to splitting and reconstructing information package
- ◆ Control M.: specialized defined
 - Traffic flow control
 - Protocol control
 - User operation control

Gateway cluster components

◆ Components

- Host gateway
 - Central routing
- Marginal gateways
 - heterogeneous networks
- CNS/ATM workstations
 - air-ground segments
- Management modules
 - Five functions

Operation with gateway cluster



Thank you!