THE IMPACT OF MM-WAVE ON CIVIL AVIATION IOT PATH

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THE CIVIL AVIATION PATH TO IOT

INTERNET OF THINGS (IOT)

- Current situation
  - There are many links for the commercial aircraft – stove pipes
  - Cockpit and cabin are separated
  - Aircraft can have more than one router
  - Cockpit apps use certain links and cabin services use other links for security requirements

- Future
  - Single router with proxy services
  - Make use of future and current aircraft links optimally and securely
  - IoT concepts are at the commercial aircraft such that a passenger experience in the air is the same as on the ground.
  - There is a role for the mm-wave in bringing full IoT capabilities to the aircraft
  - The industry is highly regulated. Regulators will influence this path

This presentation gives possibilities for gradual move towards full IoT capabilities in the aircraft -- It is not Collins policy, it is forward looking research

CABIN SERVICES

- Cabin services industry is growing rapidly
- Security of cockpit communications has to be addressed to move cabin, cockpit and crew services to full IoT capabilities
- Airlines, aircraft manufacturers and regulators must consent to any changes to the current situation
- A single aircraft router with secure IoT capabilities is a key component in addition to the use of mm-wave links for aircraft connectivity
- Cabin services that require the most bandwidth and the passenger experience is an important drive

5G CELL ONBOARD THE AIRCRAFT

Cell Type	Intended commercial deployment	# UEs	Power (watt)	Range
Femto	Residential and Enterprise	4-8	0.2 to 1	Few tens of meters
Pico	Public areas (airports, malls, ..)	64-128	1-5	Tens of meters
Micro	Urban	128-256	5-10	Few 100s of meters
Metro	Urban for additional coverage	> 256	10-20	100s of meters

A small private jet can use a Femto cell while a large airliner can use a Pico or Micro cell

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CHALLENGES

This presentation considers three challenges:

A. Evolution path of Backhaul links to mm-wave links.

B. Security implementations that will enable civil aviation regulators acceptance of full IoT capabilities onboard the aircraft.

C. The impact on the aircraft router. We need to turn the aircraft router into a mini-data center with many proxy services

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A. EVALUATION OF BACKHAUL LINK

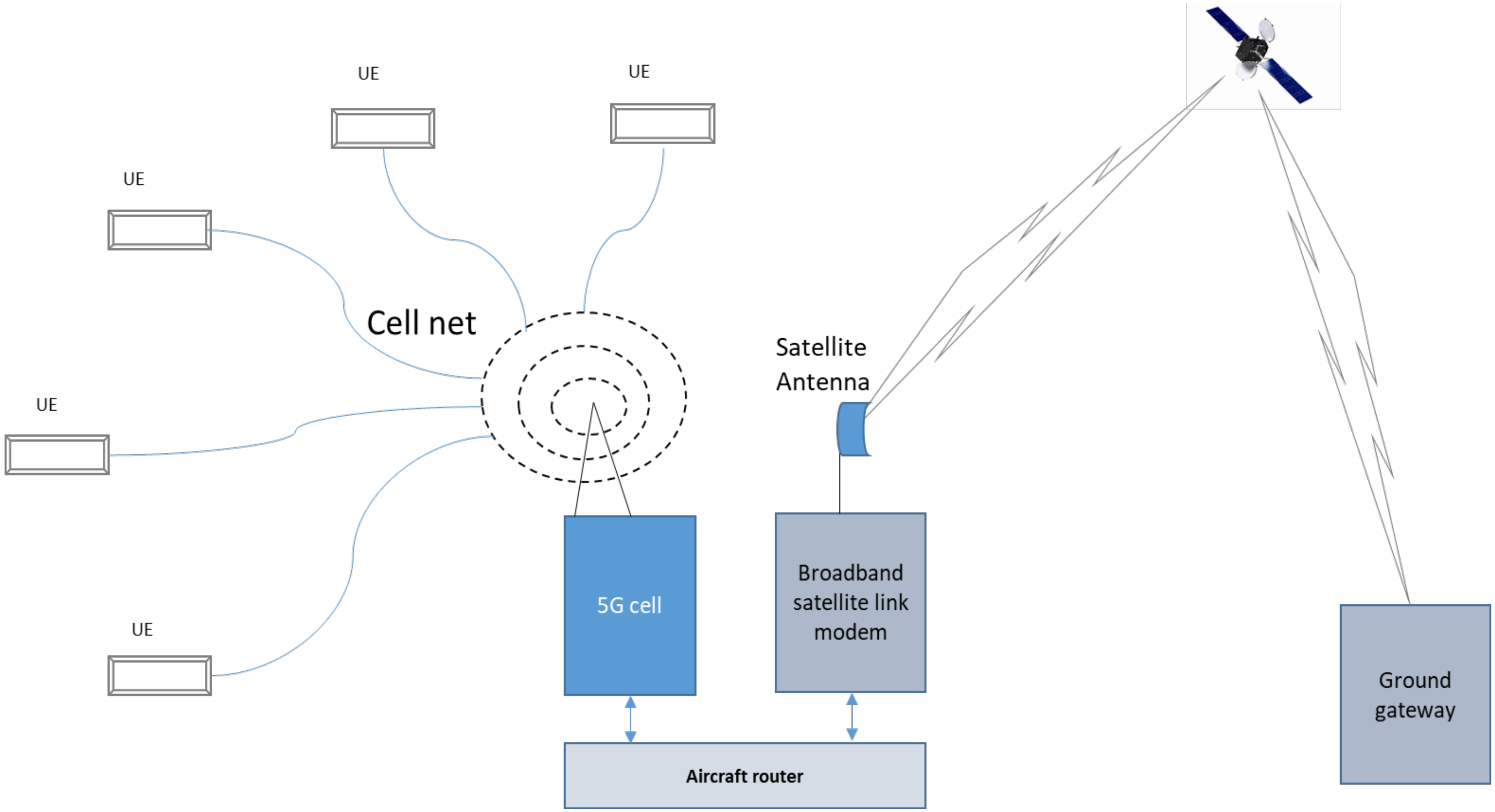
1-BROADBAND SATELLITE AS BACKHAUL

- Currently, many aircraft have broadband satellite links to a ground gateway.
- There are reasons why this method of backhauling can be the first in the IoT evolution path.
  - 5G standardization allows the use of broadband satellite for backhauling.
  - These links are already available for aircrafts.
  - Current equipment in the lower than 6 GHz range such as a femtocell or a 3GPP card are available and can be used now to offer aircraft IoT services relying on broadband satellite for backhauling.

Challenge: Different countries use different < 6GHz sub-bands. International flights have to adapt to host country frequency use

Challenge: Should the aircraft router soft configure the 5G cell based on host country frequency? Seamlessly?

BACKHAULING USING BROADBAND SATELLITE LINKS



BACK TO THE AIRCRAFT ROUTER

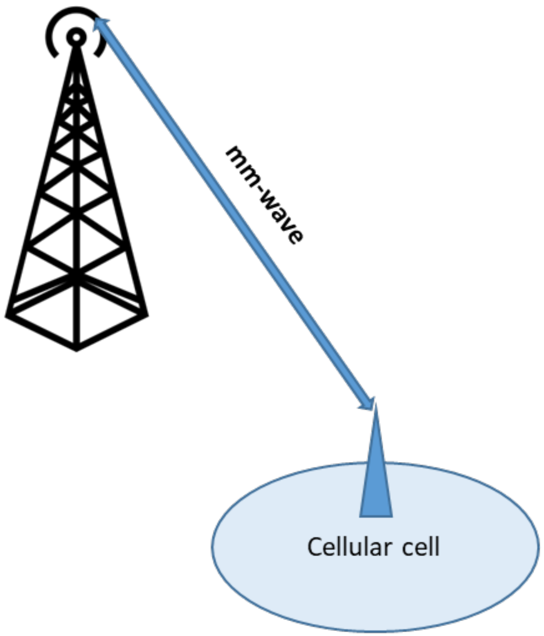
- Because the broadband satellite link may have limited bandwidth, traffic engineering in the router is needed
  - Prioritization of voice traffic over data traffic.

- Airlines are typically against making voice communications available in the cabin for passengers as it disturbs the crowded cabin. This may require router policies where 5G voice is available only for private jets.

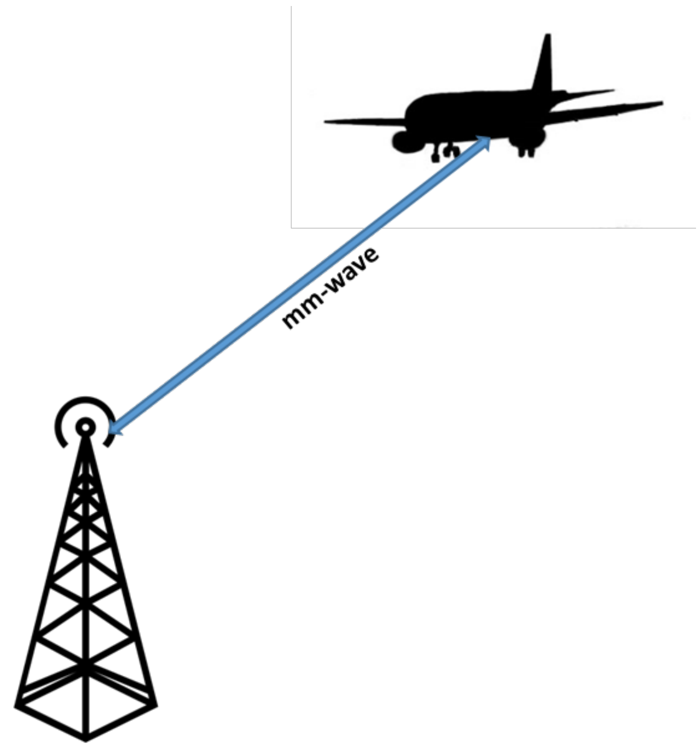
2- USING 5G GROUND INFRASTRUCTURE FOR AIRCRAFT CONNECTIVITY

- The UAS industry already has plans for using ground 5G infrastructure for lower altitude UASs.
  - Ground infrastructure can reliably create access to UAS up to about 8000 feet high.
  - Higher elevation UASs may require similar 5G access to private and passenger aircrafts.
- Using ground infrastructure for high elevation aircrafts is possible with an adaptation of the mm-wave links to aircraft needs

MM-WAVE LINKS BETWEEN CELL TOWERS AND AIRCRAFTS



Deploying 5G cells with 5G mm-wave directional links to core network



5G mm-wave links to connect civilian aircrafts to the core network

CHALLENGES AND ADVANTAGES

- Challenges:
  - The need for a massive MIMO antenna on the tower that points to the sky and can track fast moving aircrafts (for a speed up to 0.8 of Mach 1).
  - Equipping the aircraft with a 5G MIMO antenna mounted on the aircraft belly.
  - The distance between the tower and the aircraft can be as long as 15 Km.
- Advantages:
  - The 5G SON capabilities will allow seamless connectivity.
  - The mm-wave frequency used pointing up can be the same as links pointing down. mm-wave directional capabilities will not require dedicated frequency bands for aircrafts.

The DARPA 100G program demonstrated range extension of mm-wave range above 50 miles.

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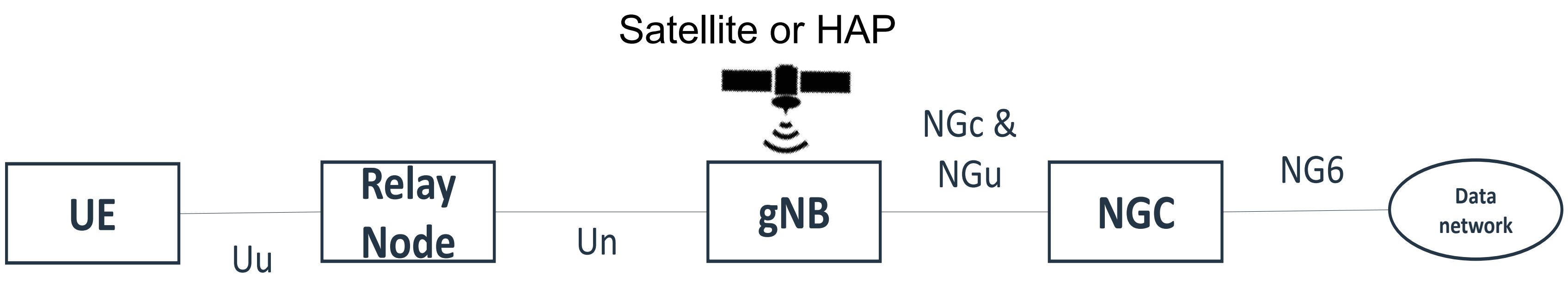
3- USING 5G NON TERRESTRIAL NETWORK

- If and when the 5G non-terrestrial RAN materializes, it will impact the aviation industry.
- The 3GPP committee has a plan for this 5G capability but it will be considered after ground infrastructure is studied and the impact of using satellites and High Altitude Platforms (HAPs) is well known.
- In the United States, the Federal Aviation Administration (FAA) and the Department of Transportation (DOT) have plans for using 5G ground infrastructure for low altitude UASs as first order of business.
- The path of the IoT for aircrafts can consider the non terrestrial 5G capabilities when it is deployed

Non-terrestrial 5G will compete with broadband satellites. Considering the higher bandwidth, lower cost and the lowering of delay time, non-terrestrial 5G can eventually replace broadband satellite all together, which is a major industry shift.

NON-TERRESTRIAL 5G NOTIONAL ARCHITECTURE



- Back to the aircraft router:
  - The relay node capabilities have to be part of the aircraft router and modem capabilities.
  - The router would need to integrate some 5G relay node hardware and software that will work with the specially designed antenna as the relay node integrating both the Uu and the Un interfaces
  - Need special MIMO antenna on top of the aircraft

B. SECURITY CHALLENGES

REGULATORS AND SECURITY

- Security is a major consideration when it comes to the aviation industry.
- There are sensitive equipment onboard a manned or unmanned aircraft that, if controlled by a malicious party on the ground, can turn the aircraft into a deadly weapon.
- Bringing full IoT capabilities to the aircraft will require special security consideration.
- The low-cost and high-bandwidth of mm-wave links will push airlines to ask the industry to find ways to securely route cockpit traffic over these low-cost connectivity links instead of having expensive special links for cockpit traffic.
- How can we achieve cockpit security with low cost links?

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CONSIDERATIONS IN ROUTER DESIGN

1. Hardware separation. Due to the sensitivity of some cockpit applications, it is important to create separation between the cabin and cockpit, and this separation can start from the hardware separation such that the cockpit is its own standalone LAN.
2. Using secure tunneling before routing over the mm-wave link with the highest level of security.
3. Using a second tunnel between the aircraft router and a ground gateway such that only the ground gateway can close the loop of the secure tunnel between the aircraft and the ground. The cockpit LAN tunnel will exist within this gateway tunnel
4. Rely on application security in addition to the cockpit LAN secure tunnel

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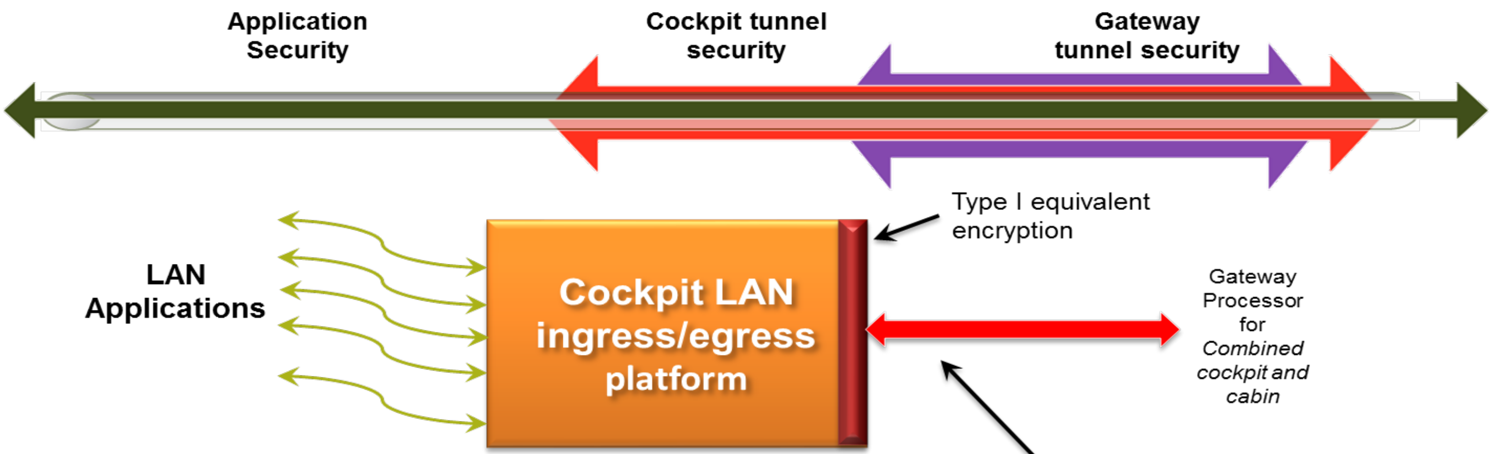
COCKPIT SECURE LAN ACCESS



- Applications can have an additional security layer
- Applications can be in house or third party
- Applications have different levels of precedence and preemption

This process will give

- DSCP based marking based on port application policies
- Prioritization based on application needs
- Based on available BW communicated from the gateway processor, can prioritize traffic
- Each application has a LAN address
- Secure access has a single tunnel address

Secure access

- Secure tunnel is FAA approved
- Although the tunnel consolidates all cockpit application, the gateway process for combined cockpit and cabin can differentiate the services between different applications

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C. AIRCRAFT ROUTER

SOFTWARE DEFINED AIRCRAFT ROUTER

- Bringing IoT capabilities to the aircraft would require a software defined router

- It is disruptive for the industry

- The end goal is to turn the aircraft router into a virtual data center that offers IoT services to:
    1. Cabin
    2. Crew
    3. Cockpit including aircraft equipment telemetry

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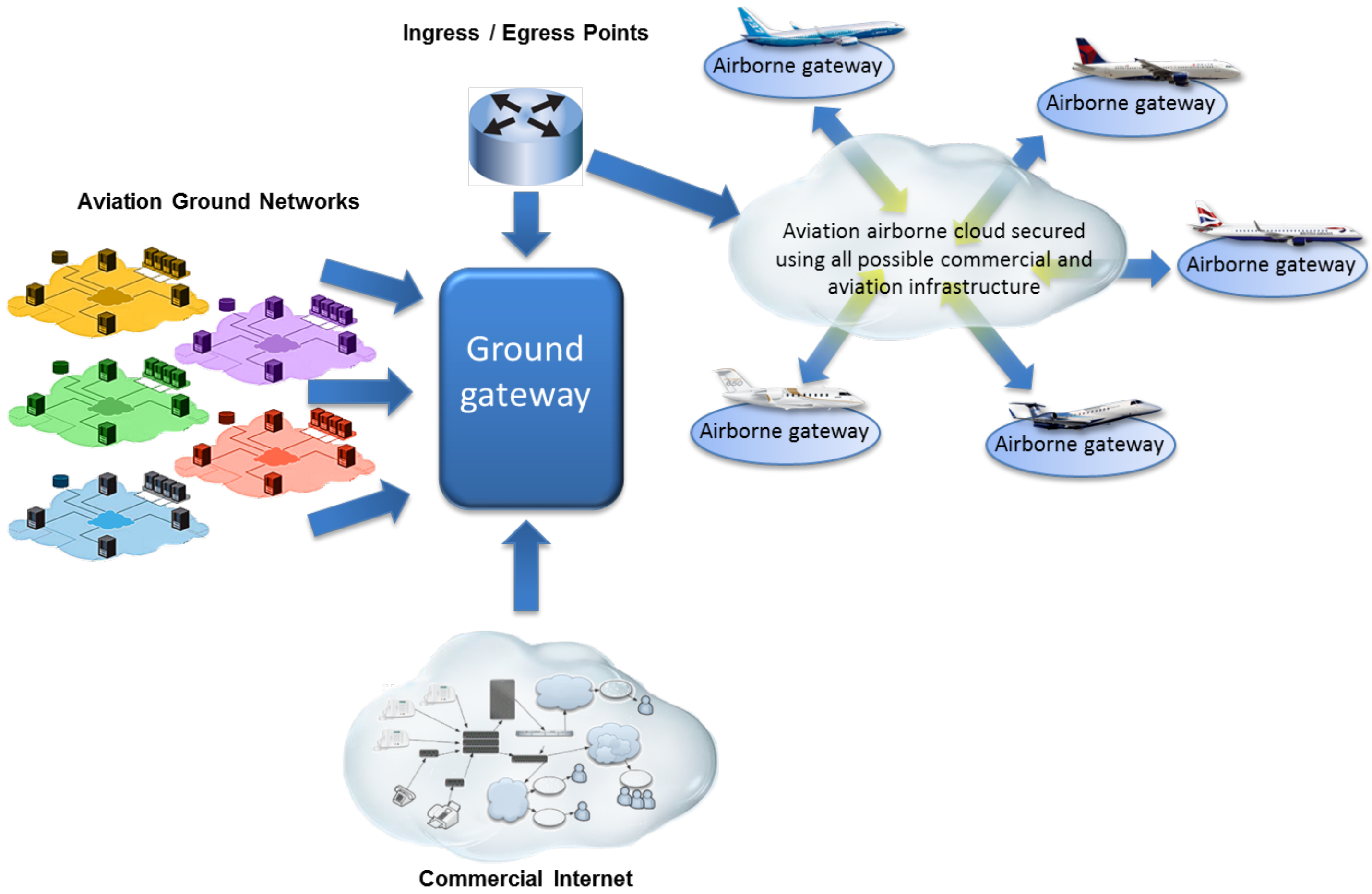
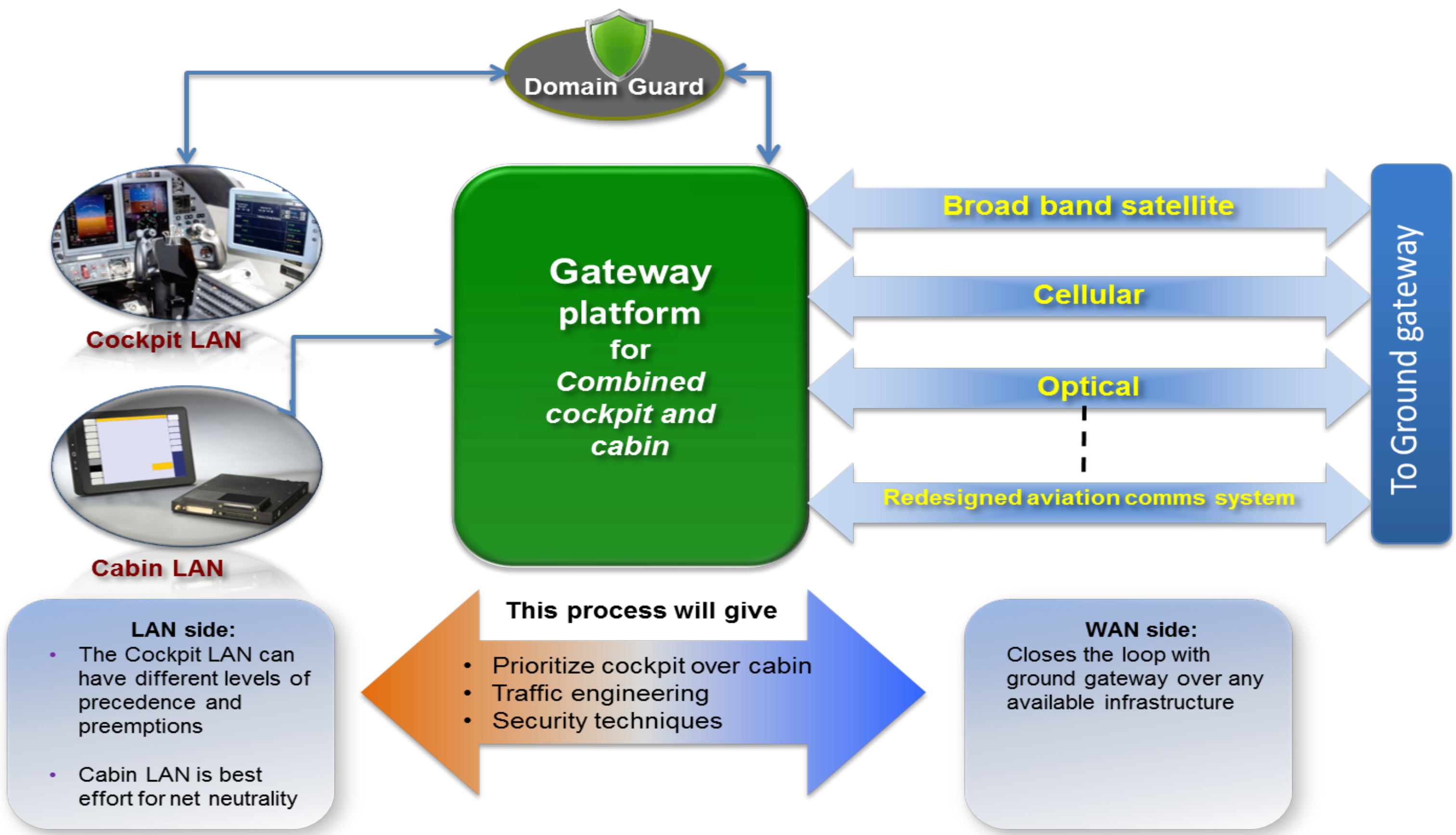
THE ROLE OF THE GROUND GATEWAY AND THE AIRCRAFT ROUTER AS AIRBORNE GATEWAY



THE LAN/WAN CONCEPT



SUMMARY

- There is a critical role for mm-wave in bringing IoT capabilities to commercial and private aircrafts
- Multistep path to IoT can be implementable
- Security is critical
- New aircraft router maybe needed

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