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Research Article

Expandable Optimum Avionics Architecture Solution with Advantage in terms of Cabling Weight for a Helicopter

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Abstract

One of the biggest problems that the aviation industry focuses on in helicopter platforms is that the payload is not at the desired level. Another of these problems is the integration problem experienced in the process of integrating current technological equipment into the helicopter avionics architecture later throughout the product life cycle of the helicopter. Increasing the payload allows to carry more personnel, ammunition, etc. An expandable avionics architecture concept enables this if it is desired to integrate new avionics equipment throughout the life of the helicopter. In this context, R&D activities are organized in order for avionics equipment to be fast, expandable and reliable, and to transfer data via lighter ways. In this study, avionic architectural concepts from the past to the present were examined and a comparative analysis was made in terms of the cabling weight that will be formed on the helicopter platform in its possible use. While creating this concept, distributed, federated, integrated and distributed integrated architectures were examined, as well as RS-422/485, ARINC-429/629, AFDX, MIL-STD-1553 and FIBRE Channel protocols within the scope of communication protocols. By examining the superiority of the mentioned concepts to each other, the cabling weight created by different avionics architectures on the platform was calculated, and the optimum avionics architecture concept, which could be expanded to create a minimum cabling weight for a military type helicopter, was proposed.

Keywords: Avionic Architecture, Fibre Channel, AFDX, IMA, DIMA.

Bir Helikopter için Kablaj Ağırlığı Açısından Avantajlı Genişletilebilir Optimum Aviyonik Mimari Çözümü

Öz

Havacılık endüstrisinin, helikopter platformlarında odaklandığı en büyük problemlerden biri faydalı yükün istenilen düzeyde olmamasıdır. Bu problemlerden bir diğeri ise helikopterin ürün yaşam döngüsü içerisinde güncel teknolojik ekipmanların sonradan helikopter aviyonik mimarisine entegre edilme sürecinde yaşanan entegrasyon problemidir. Faydalı yükün artırılması daha fazla personel, mühimmat vb. taşıyabilmeye olanak sağlamaktadır. Genişletilebilir bir aviyonik mimari konsepti ise helikopter ömrü boyunca yeni bir aviyonik ekipman entegre edilmek istenirse buna olanak sağlamaktadır. Bu kapsamda aviyonik ekipmanları hızlı, genişletilebilir ve güvenilir olmakla birlikte daha hafif yollardan veri aktarımı yapabilmesi için Ar-Ge faaliyetleri düzenlenmektedir. Bu çalışmada, geçmişten günümüze gelen aviyonik mimari konseptleri incelenmiş ve olası kullanımında helikopter platformu üzerinde oluşturacağı kablaj ağırlığı yönünden karşılaştırmalı analizi yapılmıştır. Bu konsept oluşturulurken dağınık, federe, entegre ve dağınık entegre mimariler incelenmiş aynı zamanda haberleşme protokolleri kapsamında RS-422/485, ARINC-429/629, AFDX, MIL-STD-1553 ve FIBRE Channel protokolleri de incelenmiştir. Bahsedilen konseptlerin birbirlerine üstünlükleri incelenerek farklı aviyonik mimarilerin

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platform üzerinde oluşturduğu kablaj ağırlığı hesaplanmış olup askeri türden bir helikopter için minimum kablaj ağırlığı oluşturacak şekilde genişletilebilir optimum aviyonik mimari konsepti önerilmiştir.

Anahtar Kelimeler: Aviyonik Mimari, Fibre Kanal Afdx, EMA, DEMA.

1. Introduction

Advances in the military, electronics and communication sectors have enabled significant developments in the aviation sector, especially in avionics technology. The needs of the sector in avionics technology, expansion possibilities, updatable and wide data transfer make the development of avionic BUS structures inevitable. While avionics BUS technology meets these needs, it is expected to optimize the payload by considering the weight constraints of aircraft. One of the factors affecting the reduction of the useful load in helicopters is the weight of the cabling, which provides communication between avionic equipment. However, as avionics technology develops, new generation avionic equipment is developed and it is desired to use this equipment in helicopter. Therefore, the creation of an avionics architectural infrastructure optimized in terms of payload, which can integrate newly developed avionic equipment into the aircraft, is necessary to meet this need. Migration of avionics architectures from analog to digital is getting complex, but it has cost, flexibility, weight, etc. has made beneficial progress. There have been few studies on architectural concepts in the literature (Champeaux, Faura, Gatti, & Terroy, 2016; Shah, 2014; Wang & Xiong, 2009). While research is being conducted on the maturity of avionics systems that are in the development stages, it is explained in detail the methodologies and their limitations of ongoing avionic modification from electromechanics to digital avionics (Shah, 2014). For distributed architectures with more than one connection topology, a theory has been proposed that includes a set of communication networks. The functional features of this theory have been modeled with a modular discrete event network simulator called OMNEST Framework and after validation, it has been implemented under the name of physically multi-link communication unit while preserving the ARINC 664 Part 7 AFDX features. As a result of the tested multi-link communication unit, it is stated that the proposed evolution from the central network (federated) system to the distributed network (distributed) system will be possible with the presence of many well-adapted connected communication units(Champeaux et al., 2016). It offers an AFDX-based avionics communication architecture using a high-bandwidth communication architecture that independently collects and distributes various types of signals called Wavelength Division Multiplexing (WDM) in order to manage real-time data traffic in integrated modular avionics architectures. It is stated that AFDX-based protocols do not take into account the physical transmission performance, by using the Wavelength Division Multiplexing architecture, it will meet both the real-time constraints of the avionics system and the high bandwidth demands(Wang & Xiong, 2009).

In this context, avionic architectural concepts have been developed from past to present. In this study, an expandable avionics architecture has been proposed, minimizing the cabling weight that provides communication between avionic equipment, which is one of the most effective factors in reducing the useful load in helicopters.

2. Communication Protocols Used in Avionics

2.1. Rs-422/485

The first version of the RS-422 communication protocol, developed by the Electronic Industries Alliance, was published in 1978(Wikipedia). RS-422 protocol provides message exchange using differential line. Since differential signal is used, it is more protective against electromagnetic interference and less affected by noises. The maximum transmission length varies between 12 meters and 1200 meters, although it varies according to the bandwidth ratio as specified in the standards.(Alliance, 1994). Bandwidth can be adjusted between 10 Kbps and 10 Mbps. The required cable length is determined by the communication speed. A maximum of 10 electronic equipment can be connected to a bus topology installed with RS-422. If the RS-422 protocol, which can communicate in simplex mode, is to be used in full-duplex mode, it is necessary to connect with 4 cables.

The RS-485 protocol, released in 1998 by the Telecommunications Industry Association and the Electronic Industries Alliance (TIA/EIA), is an enhanced version of the RS-422 protocol(Wikipedia, 2021b). In an avionics architectural topology based on RS-485, up to 32 equipment can be communicated and communicated in half-duplex mode with a twisted pair cable. While the bandwidth is 10 Mbps in short distances, it can go up to 40 Mbps with advanced technology electronic circuits.

2.2. Arinc-429

Arinc-429 protocol, also called Mark33 Information Transfer System, is a standard created for digital data transfer between avionic system equipment. AERONAUTICAL RADIO, INC. Published by in 1977(COMMITTEE, 2004). Communication is done unidirectionally over a twisted-pair cable. If a two-way communication is desired, 4 cables in the form of receiver and transmitter should be used. In a bus structure with a single sender, there can be a maximum of 20 receiving equipment. Bandwidth is offered in two options as 12.5 Kbps and 100 Kbps.

2.3. Mil-Std-1553

The MIL-STD-1553 protocol is a military standard published by the United States Department of Defense in 1973 that defines the mechanical, electrical, and functional characteristics of a serial bus(Wikipedia, 2021a). In this protocol, which provides data transfer using a pair of cables, a communication infrastructure can be established for up to 31 equipment over a single bus. In order for each piece of equipment to be included in the bus, it must be used from the device called stub. According to the standard, the distance of an equipment with transformer coupling to the bus should not exceed 6 meters, and the distance of an equipment with direct coupling to the bus should not exceed 0.3 meters.(Defense, 1975). The communication speed is 1 Mbps and can be used in half-duplex mode.

2.4. Arinc-629

The ARINC-629 protocol is based on DATAC (Digital Automatic Terminal Access Control) developed by Boeing and formed the basic avionics bus of Boeing 777 aircraft in

1985(Spitzer, 2001). This protocol with a bandwidth of 2 Mbps can communicate with two twisted wire cables. This protocol allows 120 pieces of equipment to exchange data in half duplex mode on a bus. Each terminal is included in the bus with units called stubs. Figure 1 shows the topology of an ARINC-629-based bus.

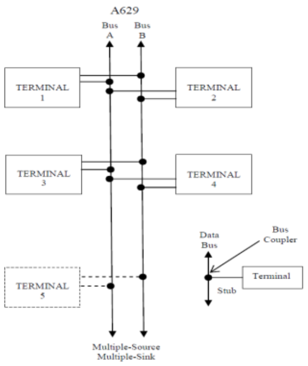

Figure 1 ARINC-629 Bus Topology (YASEMIN, 2010)

2.5. Afdx

The ARINC 664 bus protocol contains electrical characteristics and recommendations for avionic equipment. AFDX(Avionics Full-Duplex Switched Ethernet) protocol developed by Airbus aviation company is based on IEEE 802.3 Ethernet technology and standardized as ARIN 664 part 7(Schaadt). It is the version of the Ethernet protocol optimized for deterministic and real-time applications. Switching equipment called AFDX Switch is used in AFDX-based avionics architectures. In this protocol, which provides communication in simplex mode, if you want to communicate in duplex mode, 2 pairs of cables must be used. Bandwidth is 100 Mbps.

2.6. Fibre Channel

The Fiber Channel protocol was developed for use in storage (server) networks based on the new generation data transfer technology, and later became a standard by the American National Standards Institute (ANSI) in 1994. Since it was developed for high data transfer, it has a bandwidth of 10 Gbps, but in aviation applications, 1 Gbps and 2 Gbps versions are used according to cable length. It can communicate in full duplex mode with 2 twisted pair cables. Similar to the AFDX protocol, a module called Fiber Channel Switch must be used in an avionic architecture created with this protocol. Provided that the ports of the module used are sufficient, it allows 2^{24} avionic equipment to communicate together(Glass, 2007). It also offers this expansion opportunity by adding more switch modules. Figure 2 shows the topology of the Fiber channel protocol.

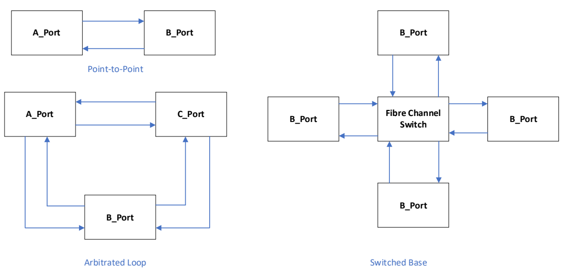

Figure 2 Fiber Channel Topologies

3. Avionics Architectures

Avionic engineers organize R&D activities to provide a good solution to issues such as cable complexity, cable weights, architectural reliability and complexity in aircraft. In order for many systems to work together to meet the needs of the aircraft and the customer, the systems need to be integrated with each other. During the integration process, avionics architectural concepts have to address these issues. Different avionics architectural concepts have been constructed from the past to the present. In this section, these avionic architectural concepts will be explained.

3.1. Point-to-Point Federated Architecture

Aircraft electrical system, fuel system, transmission systems, etc. It contains many sensors. These sensors (analog, discrete, etc.) have different interface needs. In an avionics architecture concept as in Figure 3, there is an avionic equipment that collects data from the sensors of the aircraft. This data collection unit is designed to collect various data, turn it into a digital data and transmit it to a central processor for processing. In addition, in this architecture, there is a central processor that manages the pilot interface, which keeps and processes the avionics systems such as flight control system, navigation, communication, etc. in a single center and processes the desired data(Moir, Seabridge, & Jukes, 2006). In such architectural concepts, the sensors of the aircraft system are sent to the data collection units and then to the central processor. Avionic equipment communicates directly with the central processor. Since a separate communication line must be established for each equipment, the weight of the cabling increases in direct proportion to the number of equipment, and also increases the cable complexity and maintenance costs.

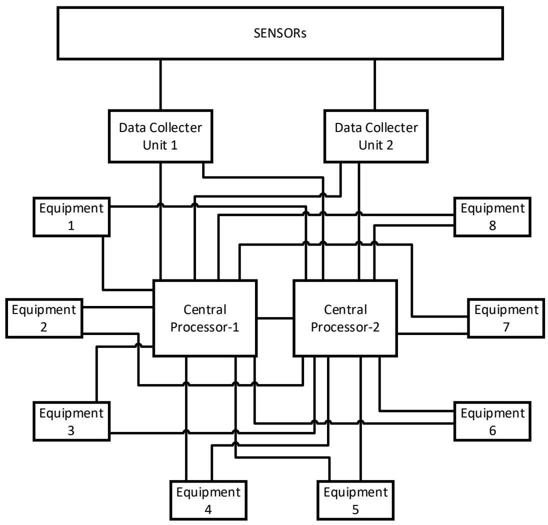

Figure 3 Point-to-Point Federated

3.2. BUS Based Federated Architecture

As can be seen in Figure 4, in this type of architectures, data paths that can handle the data load of all avionic equipment are selected and a concept that will enable the equipment to exchange messages over several data paths has been devised. Since the number of cables is small, the cable complexity is also low. Equipment on the bus is included in the system with units called Stubs. The systems of the aircraft are collected over two data collection units in the same way and these data are transferred to the central processor over the data bus. Depending on the number of equipment and the density of the data to be transferred, a high-bandwidth bus should be selected or more than one bus with narrow bandwidth should be used.

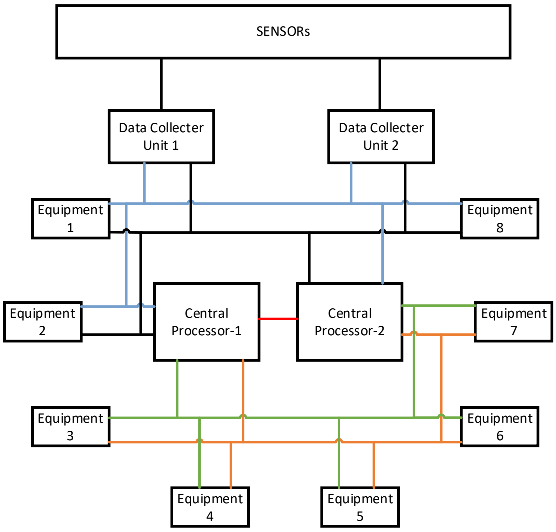

Figure 4 BUS Based Federated

3.3. Point-To-Point Distributed Architecture

As seen in Figure 5, in such architectural concepts, the sensors and avionics equipment of the aircraft are separated from the central processor by communicating with the data collection units distributed on the aircraft and a distributed path is followed. These data collection units, which are distributed to various parts of the aircraft, reduce the cabling complexity and weight. At the same time, it not only reduces the interface load of the central processor unit in federated architectures, but also offers an expandable concept.

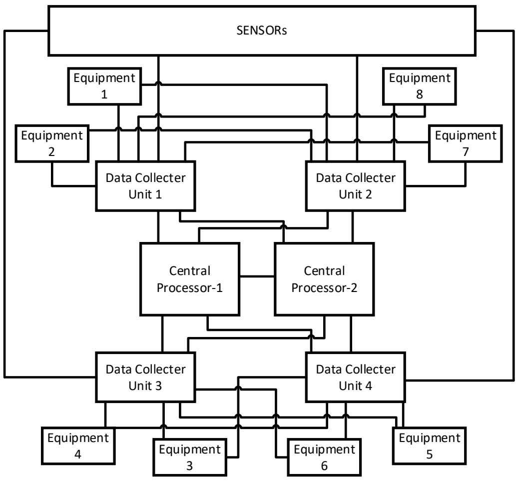

Figure 5 Point-to-Point Distributed

3.4. Integrated Modular Architecture

In this architecture, there is a cabinet containing other equipment as seen in Figure 6. Avionic equipment to be placed in the cabinet has a structure that can be removed and installed like a module. Since it communicates directly with the central processor, there is no need for external cabling.

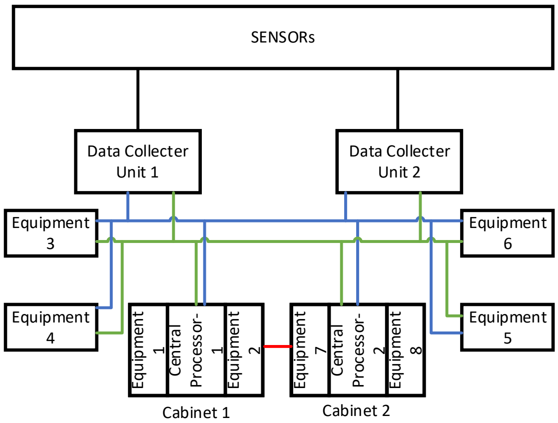

Figure 6 Integrated Modular Architecture

Figure 7 shows a cabinet used in Boeing 777 aircraft. While more modules can be placed in the avionics cabinet in large aircraft such as passenger planes, fewer modules can be placed in narrow-body aircraft such as helicopters due to placement restrictions. As the number of modules installed increases, the need for cabling decreases. In addition, in this architecture, similar to the Point-to-Point Federated architecture, there is a data collection unit that collects data from aircraft systems (fuel, engine, etc.) and converts it into digital. Data acquisition units transmit digital data to the central processor unit for processing over an avionics bus. Avionic systems (navigation, communication, etc.) that are not in the cabinet communicate with the central processor via the avionic BUS.

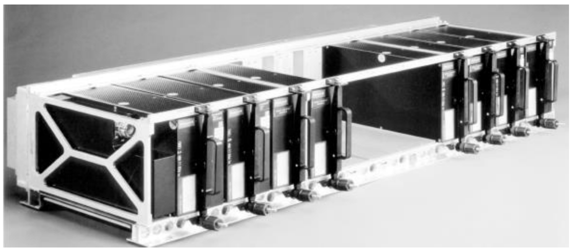

Figure 7 Boeing 777 AIMS Cabinet (Spitzer, 2001)

3.5. Distributed Integrated Modular Architecture

In such architectural concepts (Figure 8), in addition to the presence of an integrated cabinet, data collection units distributed to different parts of the aircraft collect data from avionic equipment that are not in the cabinet and aircraft sensors.

In addition, these architectures, which are built with Ethernet-based next-generation communication protocols (AFDX and FIBRE Channel), can communicate a large number of equipment and processor units using high bandwidth. At the same time, it offers endless expansion possibilities as long as aircraft space and weight constraints allow.

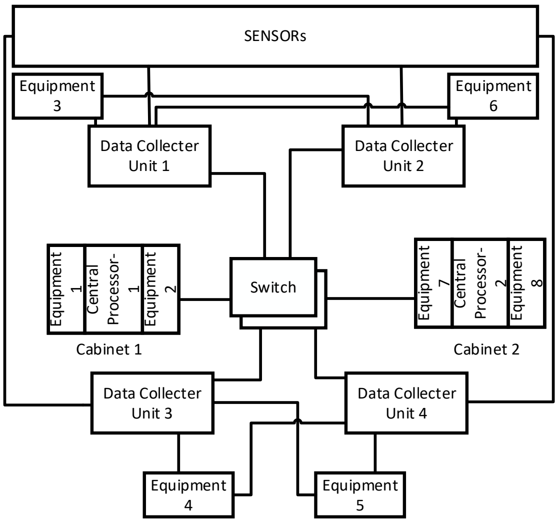

Figure 8 Distributed Integrated Modular Architecture

4. Methodology

While conducting this study, 5 different avionic architectural concepts mentioned above were applied separately in a helicopter (Figure 9) model and the weight of the cabling used in each avionic architectural concept was calculated. All the avionics and mission functions integrated into the helicopter are the same, but the avionics architectural concepts designed to integrate the equipment differ.

4.1. Pre-Admissions

While the study was being conducted, the following assumptions were stated and the following assumptions are valid for 5 avionics architectures.

- All architectures applied to the same helicopter.
- Sensors of helicopter systems and avionics equipment are located in the same area in all architectures.
- The average inter-regional cabling route distances in the helicopter are as in Figure 9 and the same distances are used in all architectural variants.

4.2. Calculation Method

In this study, 388 discrete and 146 analog sensors belonging to helicopter systems (fuel, transmission, engine, fire protection, landing gear, hydraulics, etc.) and 69 avionic equipment (Navigation, communication, flight control, electronic warfare, weapons, etc.) are integrated into the same helicopter over different architectures and the cabling weight used in these integrations has been calculated.

The following steps were followed in the integration and cabling weight calculation process:

1. The locations of all systems to be integrated are determined on the helicopter.
2. Whichever architecture type will be integrated, appropriate communication protocols have been selected.
3. Whichever architecture type will be integrated, appropriate communication protocols have been selected.
4. The cable distance and weight used between two equipment are calculated according to the end-to-end connection between the equipment.

For example, while this calculation is being made in a Point-to-Point federated architecture, a GPS equipment in the rear avionics compartment exchanges messages with the Processor Unit-1 in the front avionics compartment over the Arinc429 protocol, and 2 receivers (Arinc429_Rx_Hi and Arinc429_Rx_Low) and 2 transmitters (Arinc429_Tx_Hi and Arinc429_Tx_Low) cable will be needed.

According to Figure 9, the distance between Front avionics and Rear avionics is 8.5 meters.

Total Length=8.5*4=17 meters of cable.

A cable (M27500A24DK2N06) that complies with the aviation standard MIL-DTL-27500 should be used(Defense., 1997).

Total weight= (M27500A24DK2N06)0.012 kg/meter * 17 meters= 204 grams.

If the weight of the same communication in the Bus Based Federated architecture is calculated:

If the GPS equipment wants to communicate with the processor unit located in the front avionics compartment, it must be included in the Arinc629 BUS line located in the rear avionics compartment. In order for avionics equipment to be included in the Arinc629 BUS, connectors called stubs are needed(Rieckmann, 1997). It can be included in this BUS with 2 wire cables (Arinc629_Data_Hi and Arinc629_Data_Low) and 1 stub.

The rear avionics cable length is determined as 2 meters in itself.

Total length=2*2 meters=4 Meters

Total weight= (M27500A24DK2N06)0.012 kg/meter *4+ (stub weight)0.12 kg=168 grams

Similar to the examples given above, the weight created by 5 different architectures on the helicopter was calculated and is as in Table 1.

Table 1 Total Cabling Weights of Five Different Architectures

Architectures	**Total Cabling Weight (kg)**
Point-to-Point Federated Architecture	55,7646
BUS Based Federated Architecture	68,1872
Point-to-Point Distributed Architecture	40,4236
Integrated Modular Architecture	63,9824
Distributed Integrated Modular Architecture	28,1266

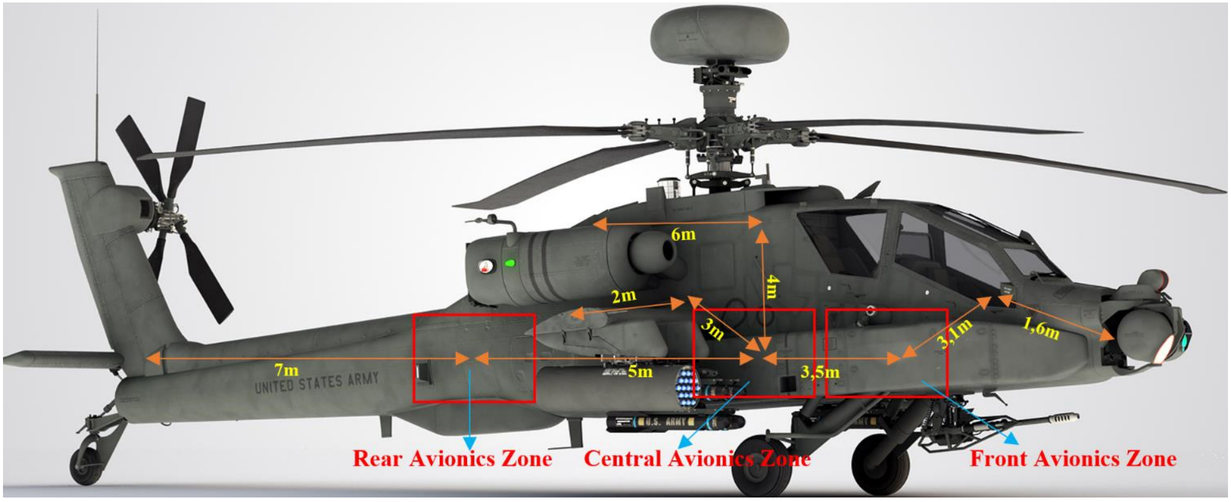

Figure 9 Cabling Lengths in Helicopter Model (Apache Longbow Helicopter)(Pekdemir, 2007)

5. Proposed Avionic Architecture

Considering the mission load of new-generation helicopters, capabilities, and advanced systems brought by the high technology, data flow between avionics equipment is quite high. Also considering that the helicopter has a service life of more than 40 years, it is inevitable to construct and design an advanced and expandable avionics architectural concept that can integrate the cutting-edge avionics equipment to be produced in the coming years(Rieckmann, 1997). At the same time, considering the necessity of maximizing the payload for helicopter platforms, the above-mentioned avionics architectural concepts and the cabling weight ratio created by the architectures built with communication protocols on a predetermined platform (Figure 9), are as in Figure 10.

As seen in Table 1, Distributed Integrated architecture creates an architectural concept that is lighter in terms of wiring in a helicopter compared to other architectural examples. Point-to-Point is the easiest type of architecture to integrate into a federated architecture because each avionics equipment communicates with the central processor on a separate line. On the other hand, Cabling complexity and possible faults are more difficult to find, and the processor's interface density is high, but its expansion capability is limited. At the same time, maintenance costs are high. In bus-based federated architectures, the integration process is complex and long. Although the cabling density is low, the stubs used while incorporating each line into the bus greatly affect the cabling weight. Expansion possibilities in this architectural concept are limited because bandwidth and insufficient interface constraints occur. Less cabling is used in a Point-to-Point distributed architecture concept because each equipment communicates with data collection units located in its own region. All avionic products on the market can be integrated into this architecture during the system design process. If the data collection unit is designed according to the number of interfaces of the equipment with different interfaces (ARINC429, RS-485, MIL-STD-1553, etc.), these avionics equipment can be integrated. In cases where the possibility of expansion is insufficient, new data collection units can be added to make it ready for new integrations. In the integrated modular architecture, equipment can be placed inside the cabinet according to the adequacy of the helicopter body. If the ARINC629 bus is selected as the communication protocol, it provides the opportunity to integrate more equipment than MIL-STD-1553 because the ARINC629 protocol provides twice the bandwidth(Defense, 1975), (Reynolds, 1996). Any architecture that uses a common bus takes longer to integrate because real-time message exchange is required. Distributed In the integrated modular architecture, all data flow is provided over an Ethernet-based switch. All avionics data is collected by the data collection unit, converted into an Ethernet-based protocol and transferred to the central processor over the switch. This architecture based on Fiber Channel and AFDX offers endless expansion possibilities. In case the interface is insufficient, it can be expanded by adding a new data collection unit, switch. In cases where the processor power is insufficient, the system can be expanded by including a new central processor in the topology. Twenty times the bandwidth of AFDX can be achieved if the Fiber Channel protocol is used(ERDİNÇ, 2010), (Institution, 2021).

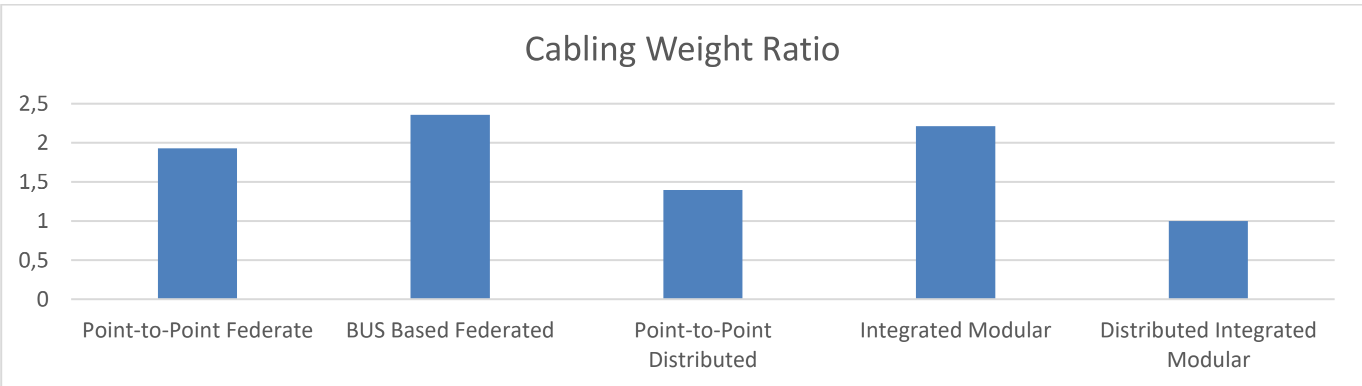

Figure 11 Cabling Weight Ratio of Avionics Architectures

6. Conclusion

While communication protocols are selected in avionics architectures, bandwidth, cabling requirement, half-full duplex mode etc. situations are taken into account. If a bus is created and all systems will be connected to this bus, a high-bandwidth bus should be selected. Considering these architectures, distributed integrated modular architecture comes to the fore when the choice is made so that the expansion possibility and minimum cabling weight are formed. When this architecture is used, both the payload will increase and if new systems are wanted to be integrated, it will allow this.

References

Alliance, E. I. (1994). Electrical Characteristics of Balanced Voltage Digital Interface Circuit. In TIA/EIA-422-B (pp. 33). USA: Telecommunications Industry Association.

Champeaux, P. B., Faura, D., Gatti, M., & Terroy, W. (2016). A Distributed Avionics Communication Network. Paper presented at the 2016 46th Annual IEEE/IFIP International Conference on Dependable Systems and Networks Workshop (DSN-W).

COMMITTEE, A. E. E. (2004). ARINC SPECIFICATION 429 PART 1-17. In (pp. 309): AERONAUTICAL RADIO, INC.

Defense, D. a. A. o. t. D. o. (1975). DIGITAL TIME DIVISION COMMAND/RESPONSE MULTIPLEX DATA BUS. In MIL-STD-1553 (pp. 43): Departments and Agencies of the Department of Defense.

Defense., A. o. t. D. o. (1997). CABLE, POWER, ELECTRICAL AND CABLE SPECIAL PURPOSE, ELECTRICAL SHIELDED AND UNSHIELDED, GENERAL SPECIFICATION FOR. In MIL-DTL-27500H.

ERDİNÇ, E. (2010). SOFT AFDX (AVIONICS FULL DUPLEX SWITCHED ETHERNET) END SYSTEM IMPLEMENTATION WITH STANDARD PC AND ETHERNET CARD. (Master). Middle East Technical University,

Glass, M. (2007). Buses and Networks for Contemporary Avionics.

Institution, B. S. (2021). Information Technology. Fibre Channel: Physical interfaces - 7 (FC-PI-7): British Standards Institution.

Moir, I., Seabridge, A. G., & Jukes, M. (2006). Military Avionics Systems: John Wiley & Sons.

Pekdemir. (2007). Apache Longbow Helicopter. Retrieved from https://www.turbosquid.com/3d-models/apache-longbow-helicopter-3d-model/372952#

Reynolds, A. P. (1996). Overview of Data Buses Commonly Used in the Aircraft Industry. Proceedings of the Institution of Mechanical Engineers, Part G: Journal of Aerospace Engineering, 210(2), 157-165. doi:10.1243/pime_proc_1996_210_357_02

Rieckmann, N. (1997). ARINC 629 data bus physical layer technology. Microprocessors and Microsystems, 21(1), 13-20.

Schaadt, D. AFDX / ARINC 664 Concept , Design , Implementation and Beyond.

Shah, G. M. A. (2014). Avionics Modification Research Analysis: From Electromechanical to Digital Avionics and from Digital to Integrated Modular Avionics (IMA). Universitat Politècnica de Catalunya,

Spitzer, C. R. (2001). The avionics handbook.

Wang, H., & Xiong, H. (2009). A novel data communication network architecture for integrated modular avionics. Paper presented at the 2009 IEEE/AIAA 28th Digital Avionics Systems Conference.

Wikipedia. (14 Ekim 2021). RS-422. Retrieved from https://en.wikipedia.org/wiki/RS-422

Wikipedia. (2021a). MIL-STD-1553. Retrieved from https://en.wikipedia.org/wiki/MIL-STD-1553

Wikipedia. (2021b, 4 Kasım 2021). RS-485. Retrieved from https://en.wikipedia.org/wiki/RS-485

YASEMIN, I. (2010). ARINC 629 Data Bus Standard on Aircrafts Avionics.