The Use of a Wireless Token Ring Protocol to Monitor Vital Data in Mute Swans

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Abstract— In this study, we obtained a license for a packet radio communication device (2.4GHz transceiver) equipped with a token ring protocol and attached it to mute swans (Cygnus olor) around Lake Teganuma, Abiko city, Japan, on a trial basis to collect vital data for potential screening purposes. As avian influenza is known to be transmitted from birds to humans, so further knowledge about the health of wild birds could prove useful for disease prevention. The heart and respiration rates of the swans could be monitored through a terminal attached to the back of the thoracic wall with 3-axis angular velocity sensors. Although many communication protocols have been reported for packet radio communication, in this study, we selected and implemented wireless token rings that were considered suitable for a flock of swans, and then confirmed the results of the field operation. In this experiment, although the number of terminals that participated was small, it was confirmed that the communication protocol smoothly shared files without congestion because the transmission right of the token ring could be turned by the accurate time of GPS. In the future, we would like to develop equipment that is smaller and lighter and adjust the communication protocol to monitor more wild birds.

Keywords—Avian influenza, angular velocity, packet wireless communications, bird-to-bird communication

I. INTRODUCTION

A. The Spanish flu is was an avian flu

In October 1918, in a part of the Arctic Circle, that is now the Svalbard Islands, a Norwegian archipelago, six young men intended to visit a gold mine. However, while they were traveling by ship, they contracted the Spanish flu, which was prevalent at the time, and then died one by one after landing. Their remains were buried 1.8 m underground, and froze quickly, thereafter.

It has been about this island, the most famous frozen island in the world, that, "you can't die on this island, because you are unable to return to the earth."

Nearly 70 years later, researchers in London discovered these records and summoned researchers from Canada, the United States, and Norway to recover the remains of these six men. Ninety-two tissue samples were collected from the carcasses, and the virus was successfully isolated. It was later determined that the virus was not of pig origin, but rather, the avian type (prototypical influenza A virus subtype H1N1), which has been involved in all three major pandemics occurring in the past century.

B. Human sialic acid receptors

Sialic acid is a complex carbohydrate with long hydrocarbon chains called ceramides. As a component, it is present at the end of sugar chains on the surface of cell membranes and plays an important biological function. Numerous types of sialic acid receptors are known, and it is noteworthy that these are associated with carcinogenesis. The influenza virus binds to sialic acid receptors in the respiratory and digestive systems in the early stages of the disease. The two main receptors are commonly called sialic acid receptors because there is a sialic acid at the tip of this complex carbohydrate. Sialic acid receptors are found deep in the lungs (in the respiratory bronchi and part of the alveolar cells) in the form of α-2,3 or avian-type receptors, while the upper airway is predominantly composed of α-2,6 or human-type receptors. This is especially true in infants, which explains why pneumonia is more severe in infants infected with Influenza A virus subtype H5N1 [3]. In addition, although the frequency of occurrence is not high, the α-2,3 types appear in human small intestinal epithelial cells at different times of the year [4].

This means that human genes have two types of sialic acid receptors, α-2,3 and α-2,6 types like pigs. However, in both pigs and humans, gene expression is extremely rare in organs that express two genes at the same time. As shown in the figure 1, it is the alveolar level in childhood and the small intestinal wall. Both types are expressed only in pellets, and without these intermediate hosts, the avian types are not able to be transmitted to humans, contrary to popular belief.

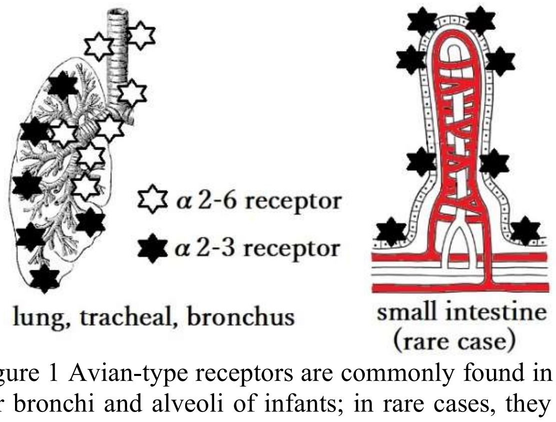

Figure 1 Avian-type receptors are commonly found in the lower bronchi and alveoli of infants; in rare cases, they are

also found in the small intestine. Receptors that can transmit avian influenza directly can also appear.

C. Propagation pathways

The general hypothesis is that the virus mutates from the original species and becomes less virulent over time. This is because the host dies when it is highly toxic, so even if it mutates and becomes highly toxic, the host dies and the virus cannot be transmitted, so the highly toxic virus cannot survive for a long time.

In contrast, a virus is more capable of propagating itself over time if it transmission has occurred between many individuals (WHO Pandemic H1N1 2009). The pandemic declaration is the same as the seasonal flu in the swine form, and the swine form is the same as the seasonal flu over time. It should be noted all three major pandemics occurring in the past 100 years have been caused by the avian type. Therefore, a screening system for avian influenza virus that takes the health of wild birds into account needs to be developed.

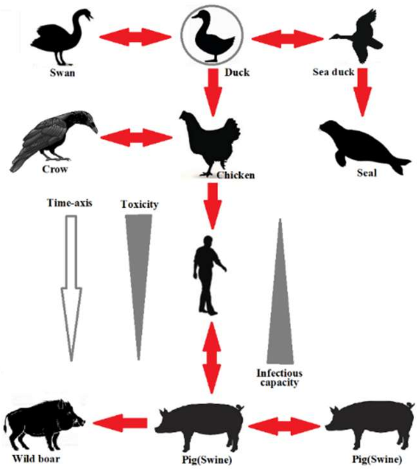

Figure 2 Routes of transmission of avian influenza virus from birds as depicted in a literature review

Figure 2 shows the routes of transmission of avian influenza virus from birds to pigs. The theory that influenza comes from pigs is not based on any known genetic, statistical, or social evidence.

II. METHODS

Physiological data (e.g., heartbeat, respiratory rate, exercise data) and individual movement data are considered basic data necessary to screen for avian influenza virus infection. Therefore, in this study, to collect these data from wild birds, we developed an attachable packet radio communication device. Specifically, we developed a wireless token ring protocol to monitor communication between flocks of birds, and confirmed that physiological data could be collected from Japanese pheasants.

Based on these experimental data obtained from pheasants, we obtained official approval (Katashiki Nintei: Radio equipment that is required to pass the certification conducted by the Minister of Internal Affairs and Communications for the model according to the provisions of the Radio Law) for 28 wireless devices (27 for users, 1 for the tracking station) from the Center for the Promotion of Effective Utilization of the Radio Spectrum under the umbrella of the Ministry of Internal Affairs and Communications of Japan, as very few types of advanced multimedia equipment are capable of being attached to wild birds for the collection of vital data. The main communications device was an S-band transceiver (CC2500; Texas Instruments), and the specifications of the output radio waves met the standards of the Association of Radio Industries and Businesses. These devices were attached to three mute swans (*Cygnus olor*) around Lake Teganuma, Abiko city, Japan, and evaluated with the cooperation of the Yamashina Institute for Ornithology and the Abiko city Museum of Birds.

A. Proposed protocol

The token rings used the IEEE 802.5 LAN protocol proposed by IBM before the spread of the Internet [13-16]. This protocol suffers from the disadvantage that communication over the entire network will come to a halt if a tablet (transmission right) disappears for any reason. For this reason, it has not been used in wireless communications, where there is a high risk of tablet disappearance. We devised a method to prevent tablet disappearance by setting virtual tablets to a time schedule in advance. In practice, each terminal acquires an accurate clock from a Global Positioning System (GPS) receiver; this is used to achieve macro-synchronization. As shown in Figs. 3 and 4, tablets are moved in sequence over time, which allows more terminals to participate in a network in sequence on the same frequency. Each terminal receives the respective signals and assesses the receiving power for individual stations in parallel, making it possible to record the distances from other stations on a list based on the free-space propagation loss formula. Sharing this list enables the diagram to be plotted in virtual space. In the case of trouble with the GPS receiver, the system can recognize the network topology calculated based on the received signal strength indicator.

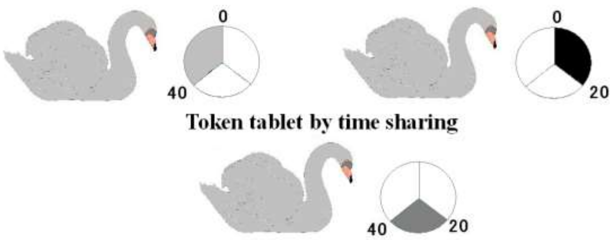

Figure 3 Token ring schematic diagram

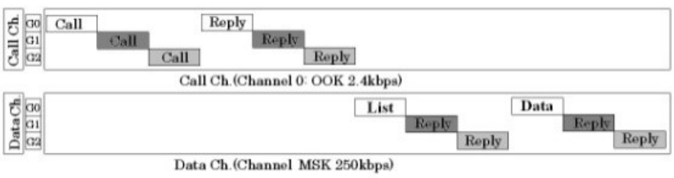

Figure 4 Packet transmission timing (for n = 3)

B. Hardware

The CC2500 communication device is equipped with the following functions, all of which are managed by a 32-bit

ARM CPU powered by a 3.7 V Ni–Cd battery (800 mAh capacity) and 450 mW solar panel. The S-band antenna is a 3/2-λ horizontal whip antenna.

Other onboard functions are as follows;

1. 3-axis angular velocity sensor for vital data
2. GPS receiver for location and time
3. Light sensors for Geolocator(If there were lack of power to drive GPS, estimate the approximate position from the time of sunrise and sunset, based on CPU's timer)

The board weighs 80 g, but when put in a thick acrylic case (to protect from chewing damage by the swan) and waterproofed, the total weight was almost 200 g (Figure 5), which is slightly lighter than the earlier ARGOS system terminal (250 g).

Figure 5 Hardware

C. Internal structure

The low-power S-band (2.4 GHz) packet transceiver is capable of transmitting data at rates from 1.2 to 500 kbps. The FIFO serving as memory for the packets was extremely small (64-byte capacity), but still capable of handling larger packets when used in combination with the interrupt function. The modulation methods available were 2FSK, GFSK, and MSK. For structural reasons, the error correction options—forward error correction (FEC) or Manchester encoding—could not be used in combination. The independent automatic repeat request (ARQ) function was disabled during the FEC measurements. A schematic of the device is shown in Figure 6.

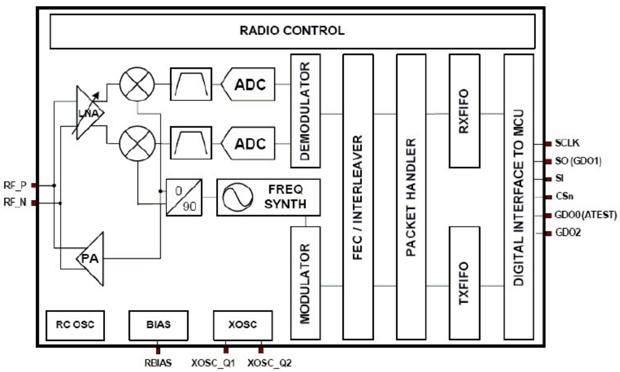

Figure 6 CC2500 internal configuration

D. Comfiremed the improvemnt with FEC

Figure 7 shows the results obtained from testing using conditions described previously[4-6]

With FEC(–) encoding, cyclic redundancy check detection errors occur at a rate of roughly 10%, even under communication conditions characterized by sufficient gain, with receiving power between –64 and –55 dBm. This corresponds to a communication distance between 66 and 200 m, or close to 90% of the area serviced. This capability likely corresponds to the price of the commercially-available CC2500, but all errors are corrected if set to FEC(+); that is, FEC(+) is an essential condition if the CC2500 is used as the basis of multicast communication in a token ring system.

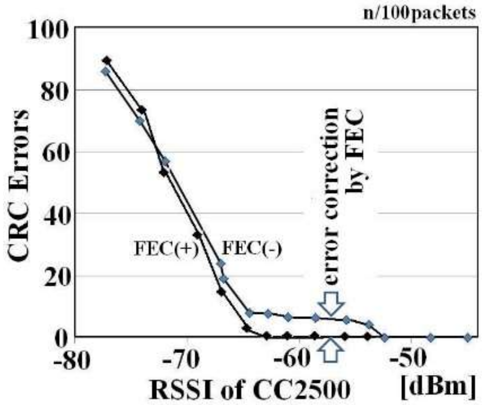

Figure 7 Error frame correction using FEC

E. Biometric data (Japanese pheasant)

An angular velocity sensor was used to obtain vital data (heartbeat and respiration rate) from outside the body. Regarding the sensor, we used the ENC-03RC (Murata Manufacturing, Figure 8), which is a so-called piezoelectric vibrating gyro module with an inner tuning fork, which is arranged on the CPU board in three axes.

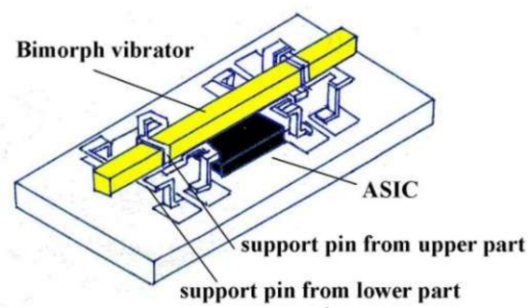

Figure 8 Internal structure and illustration of angular velocity sensor (ENC-03RC)

Attaching this sensor to the chest (back) of Japanese pheasants allowed heartbeat and respiration to be monitored. The recorded vibrations were then compared with electrocardiograms (ECGs), a fast Fourier transform was performed, the target frequency was extracted, and the waveform was reconstructed using inverse fast Fourier transform (IFFT) (Figures. 9–11).

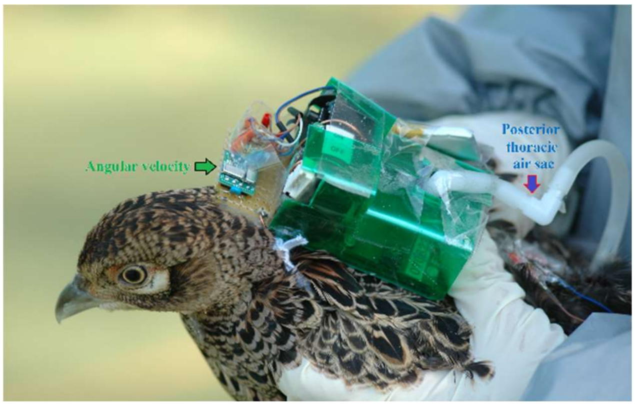

Figure 9 test of ENC-03R with Japanese pheasant

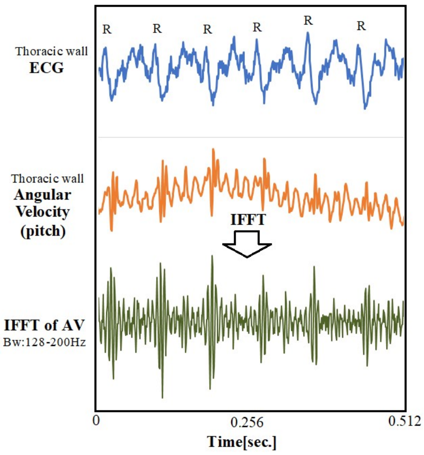

Figure 10 Obtained heart beat by IFFT

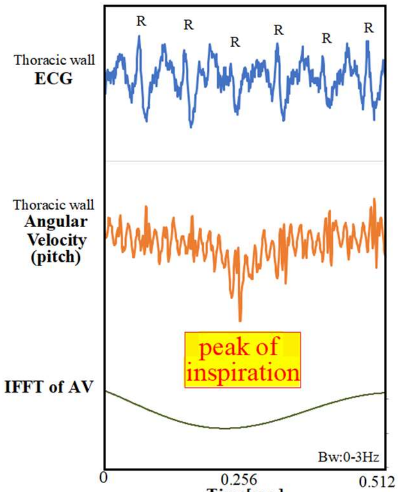

Figure 11 Obtained respiration by IFFT

F. *Field Operation at Teganuma*

Mute swans were imported from Europe during the Showa period (CE 1926–1989) and released for ornamental purposes in lakes and parks throughout Japan. The offspring of the swans around Lake Teganuma have become wild. Mute swans are characterized by their large size, relatively slow movement, and low fear of humans. For these reasons, three mute swans were selected for our monitoring operation (Figure. 12).


Figure 12 The Mute swan and transceiver

G. *Operation results*

In this experiment, although the number of terminals that participated was small, it was confirmed that the communication protocol smoothly shared files without congestion because the transmission right of the token ring could be turned by the accurate time of GPS.

Regarding the vital data, the depictions of the heart and respiration rates are basically the same as those used for the pheasant, but the selected frequency was different. Figs. 13–15 show some of the data obtained during this operation. Due to the fact that the birds act freely in nature and the tension of the braided string was relatively loose, vibrations from the heart reached the substrate through the chest wall with noise; thus, it was more difficult to detect the heartbeat in the swans than in the pheasants.

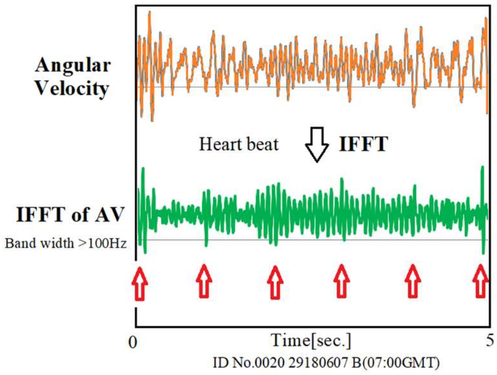

Figure 13 Hear beat (51/min.) are recognized by IFFT

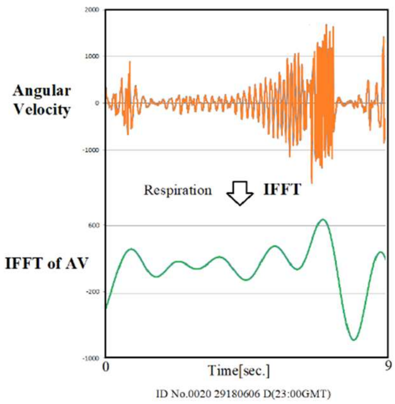

Figure 14 Inspiration and expiration can confirmed by IFFT. Storing wave with slow rate.

H. Navigation data

If the battery voltage was maintained, the behavior of the swan could be grasped at 3:00, 7:00, 15:00, and 23:00 GMT. The obtained example is shown in Figure 15.

Figure 15 The activity of No.21 swan(navigation data with GPS receiver at 03:00, 07:00, 15:00, 23:00 GMT)

III. CONSIDERATIONS

A. Avian respiration patterns and peak-to-peak heartbeat intervals

Although the literature on avian influenza infection and chickens has been summarized in a review[19], our study adapts a non-contact measurement method using an angular velocimeter to wild birds. Instead of being constantly restrained by a gauge like chickens, they are free to fly with antennas, transmitters and power on their backs.

The data obtained from the angular velocity sensor through chest vibrations could be used to determine the intervals between the heart and respiration rates. By pricking the axillary artery of a chicken and continuously measuring blood pressure directly from the cannula, the R-R interval (R-wave taken by an ECG) can be recorded simultaneously, as shown in Fig. 16. Unlike in mammals, where the "sinus node" can manage the heartbeat independently, the heartbeat in birds is controlled by the brain via the autonomic nerves, and blood pressure and the R-R interval are synchronized and fully controlled by the brain.

In the early stages of severe infection, such as by influenza, chemical transmitters released from mast cells and lymphocytes increase the permeability of blood vessels and make it difficult for blood pressure to be maintained. In humans, this results in a complaint of "lethargy", but in birds, autonomic control is disrupted to maintain blood pressure. We aimed to detect this in the peak-to-peak heartbeat intervals.

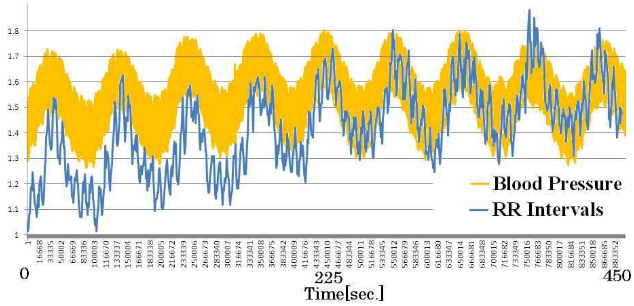

Figure 16 Changes in direct blood pressure and RR intervals of female chicken

B. Merits of Token Rings

Birds often form a flock, and when analyzed from a communications point of view, wireless terminals are concentrated in a specific area. If one terminal has all the information, and if the center can communicate with that terminal, the group data can be obtained. Considering broadcast communication with eight terminals, the results were as follows. We obtained the time required to share one file among eight terminals, varying the register setting for the transmission output with a physical attenuator inserted between antennas and terminals and set to ensure identical receiving power for each terminal. Using the token ring system, a full connection was achieved after five transmission tokens had circulated, taking 100 s (5 × 20 s). With the ARQ system, the acknowledgement and negative-acknowledgement signals increased dramatically for weaker signals (lower than –62 dBm), even when two call channels were used (Figure 17); thus, this is a clearly inferior communication system for terminals characterized by limited power supply. It should be noted that the error rate was close to zero for both systems above –62 dBm, with little difference between the two.

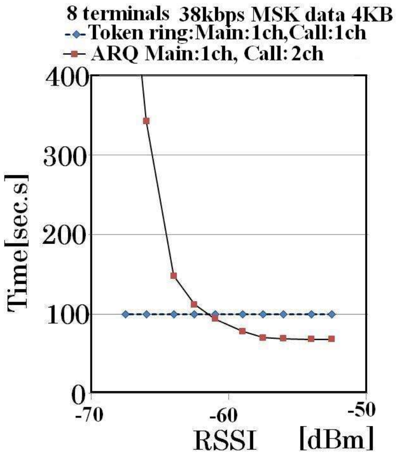

Figure 17 Comparison of time required ARQ packet wireless communications v.s. Token rings with 8 terminals.

In this study, we gradually increased the number and tested 30 terminals and parameters. If the signal strength was higher than –62 dBm, the ARQ system was more efficient (up to 16) if the conditions were good. These data were confirmed by simulation [**]. Of course, we are fully aware that the ARQ system was more efficient in this experiment, which was conducted with three units. Therefore, the wireless token ring communication protocol has a view to the future, considering the advantages of formations in which many terminals are densely packed, such as a flock of wild birds.

With cable-based token ring systems specified by IEEE 802.5, the network cannot be restored if a terminal fails, after which, packets cannot be received normally or cleared [12–14]. Similar conditions arise if a token disappears during transmission. To handle situations such as this, monitoring rights are assigned to special terminals, and functions are implemented to reissue a token if it is not circulated for a preset period of time. Another function bypasses defective nodes by directly connecting the ring input and output to isolate a failed node.

Wireless communications are susceptible to congestion, and it has traditionally been considered extremely difficult to implement a token ring system using tablets, as in cable-based systems. In this study, we adopted a system to assign numbers to certain call signs, group them by divisors, and assign tokens using a time-sharing method. We implemented this system for packet radio communication and demonstrated its effectiveness in validation testing. We believe a communication protocol such as this is applicable to situations involving multiple terminals or micromachines inserted into living organisms when direct communication between a terminal and a center is not possible.

IV. Conclusion

We obtained a license for a packet radio communication device equipped with a wireless token ring protocol and attached it to mute swans around Lake Teganuma in Abiko city, Japan, on a trial basis to collect vital data. Heart and respiration rates could be monitored through a terminal attached to the back of the thoracic wall with 3-axis angular velocity sensors. Avian influenza is known to be transmitted from birds, so this equipment may be able to screen the health of wild birds. In the future, we would like to develop equipment that is smaller and lighter and adjust the communication protocol to monitor more wild birds.

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