WHITE PAPER – GROUP DATA COLLECTION

COLLECTING USER PERFORMANCE DATA IN A GROUP ENVIRONMENT

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GROUP DATA QUICK LOOK SUMMARY

THE CHALLENGE

Collect/Display/Analyze/Control data from many low power sensors in a real time connected environment.

- Ultra Low Power Sensors With Radio Interfaces
- ANT+ / BLE Support
- Bi-Directional Communications
- Multiple Protocols Supported
- Densely Packed Radios
- Distributed Radios Across Facility

THE SOLUTION

Utilize a bridge product like the WASP-N or WASP-PoE to connect the ultra-low power ANT+ or BLE radios to groups of sensors or equipment for applications aggregating, displaying, and analyzing data. With data from an entire group of people engaging in an activity, group applications bring the workout experience to a new interactive level for both instructors and participants.

This white paper details the different technologies used in the industry for monitoring performance data from body worn sensors such as heart rate monitors and fitness equipment - items typically found in the modern health club, and sheds some light on the best practices for getting access to the data generated by these devices. The sections of the paper dive into subjects such as

- Interconnect Technologies
- Real-Time Monitoring of Multiple Devices
- Real-Time Control of Multiple Devices
- Data Collection Topologies
- Established Equipment Profiles
    - Fitness Equipment-Control Profile

The well-established ANT+ ecosystem is perfectly suited to support the group monitoring challenge by utilizing publicly available profile definitions without interfering with all other personal use cases currently employed.

Bluetooth Smarts' availability on millions of handheld devices make it well suited for personal access to sensor and equipment data, but poses unique challenges when used in a group monitoring environment.

This paper explores the similarities and differences between both solutions and some recommended best practices. Additionally, some insights into the future landscape for the group monitoring environment are discussed to help provide a roadmap for future product development.

Products such as the WASP-N2 and WASP-PoE2/3 from North Pole Engineering provide a hardware solution to support multiple sensors and equipment across both distributed collection areas and densely packed environments. Given the modular nature of the WASP ecosystem, a system can be scaled to support any size facility, utilizing existing facility infrastructure, and handle very dense radio environments as part of the overall solution.

CONTENTS

INTRODUCTION

The sports and fitness marketplace has seen an explosion in the number of devices used to monitor, collect, and report personal performance data. Many of these devices are personal body worn sensors owned by individuals performing the activity. In addition to the body worn sensors, the fitness equipment itself has the ability to measure the performance of the individual using the equipment. Most of these pieces of fitness equipment have a local display that communicates the performance information to the individual during the workout. The common theme between the body worn sensor and the fitness equipment is the need to move the data from the individual device to some other location where the data can be used by the person performing the activity. Typically this is done in a one-to-one or few-to-one configuration where the data from a heart rate monitor and some other combination of sensors or devices is sent to a watch or smartphone for collection, display, and analysis. The common mechanism to transport the data is to use a low power personal area network radio to communicate the data. This data by itself is not valuable without an application providing relevancy within the context in which it was collected. The typical application simply provides the real-time data for personal use by the individual performing the exercise.

Group fitness classes, led by an instructor, are a popular way for individuals to work out. The opportunity to utilize the data from body worn sensors and data enabled fitness equipment provides instructors and participants new ways to interact with the data. The challenge is constructing a system that minimizes individual set up without interfering with the personal data collection model already in place. This is possible utilizing ANT+ protocol enabled devices. Bluetooth smart is the other communication protocol available on many devices. This paper details the opportunities and challenges of using both types of radios in a group collection environment. The focus of the paper this to show how WASP technology from North Pole Engineering is utilized to collect the information from multiple sensors simultaneously in the group environment and make it available for applications to monitor, collect, and visualize the group activity.

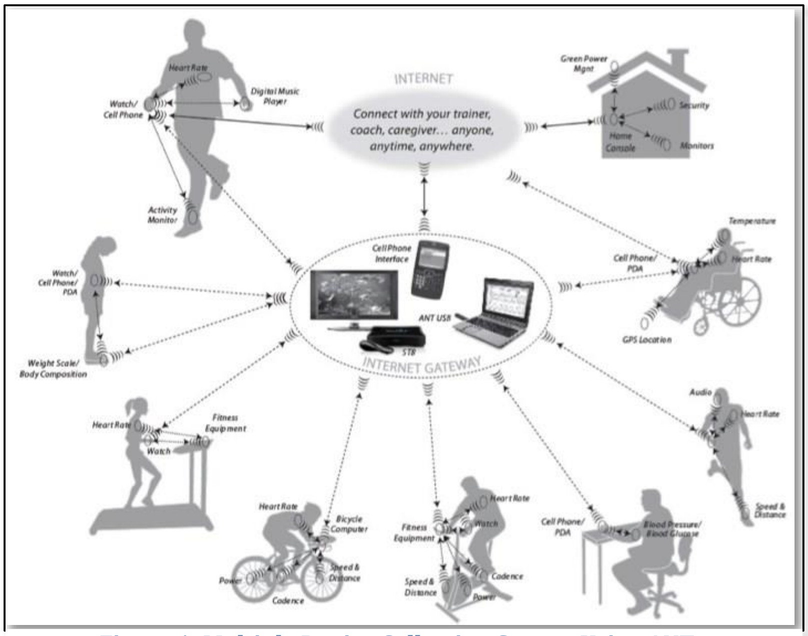

Figure 1: Multiple Device Collection System Using ANT+

Interconnect Technologies

There are many ways to move data from sensors in equipment, but two technologies are most prevalent in the marketplace. Both of these technologies utilize ultra-low power 2.4GHz radio transmission and are known as ANT+ and Bluetooth Smart. Each of the radio protocols has their own strengths in a connected system, and when used in conjunction with each other provide a complete consumer solution.

ANT+

ANT+ is a profile definition riding on top of the ANT radio communications protocol. Dynastream is the company regulating the ANT+ profile definitions to ensure any product bearing the ANT+ logo will interoperate with any other product displaying the ANT+ logo, provided they support the same profiles. The radio topology for ANT is defined with the sensor being the master and the display device being the slave. The master in the system defines the transmission rate for the communications with 4Hz being the typical standard for responsive devices, and 0.5Hz for devices operating 24/7 with infrequent changes to data. Display devices can "pair" with the sensors. The pairing process typically requires an initial scanning period where the desired sensor should be the only ANT transmitter in range of the display device. Once the paring process is complete the display device remembers the device ID of the sensor and exclusively looks for that device the next time a connection is requested. Proximity pairing can be employed to enhance the pairing process when multiple sensors are present during the initial pairing process.

Given the master/slave relationship of ANT sensors, multiple display devices can simultaneously receive data from a sensor without interference. Care needs to be taken when attempting bi-directional communication to protect against interference from multiple transmitters. The ANT protocol is a listen before talk protocol. This protocol implies that the master will look for an open time slot on the RF channel before starting its periodic transmissions at the designated transmission frequency specified by the device profile. At the end of every transmission, a device enabled for bi-direction communication will listen for a message from a slave during a short listening period.

Additional information about the ANT protocol can be found at http://www.thisisant.com/resources/ant-message-protocol-and-usage/

Bluetooth Smart / BLE

Bluetooth Smart is a protocol extension of the Bluetooth specification and is managed by the Bluetooth SIG. Other names for the protocol are BLE, BTLE and Bluetooth 4.0. BLE is an ultra-low power radio with similar performance characteristics to ANT. The major difference from ANT is the designation of master/slave. For BLE, the sensor is known as the slave/broadcaster and the display device is the master/observer. This is opposite of the ANT protocol. When the sensor device is acting as a broadcaster it sends an advertisement packet rotating through three 2MHz wide channels spread throughout the available RF spectrum. Any number of observers within range of the broadcaster can receive the advertisement while the broadcaster is transmitting. A typical BLE sensor will advertise at a fast rate at the beginning of its advertising period, and will progressively slow its advertisement rate over time to reduce the battery consumption. With a slower advertisement rate, the chance of the observer missing an advertisement increases. This happens because the advertisements are sent on three separate RF channels on a rotating basis. Since the observer can only listen on one channel at a time the broadcaster and observer may be on different channels and miss the transmission. Additional information can be requested from a broadcaster by having the observer issue a scan request message. This causes the device to send an additional message containing information from the broadcaster.

The biggest difference between BLE and ANT protocols is the concept of a connection. With BLE, if the observer wants to get more information from the broadcaster or send information to the device, it requests a connection with the device. Once the connection is established the broadcaster will typically stop advertising, causing the device disappear from all other observers. With the adoption of the 4.1 specification a device is allowed to continue broadcasting while a connection is established allowing it to continue communicating smaller amounts of data to multiple observers. Before the release of the 4.1 specification, the 4.0 specification called for the broadcaster to stop advertising once the connection is established. The connection is the only mechanism to allow the observer to send data to the device for control requests.

Real-Time Monitoring of Multiple Devices

In the world of health and fitness, there is a need to collect data from a group of people using many sensors simultaneously. In many cases each person will use multiple sensors during a group activity. In a class of 50 people there can be three transmitters per person for a total of 150 radios to monitor. In this extreme case, it is challenging to receive data from all of the individual transmitters in a real-time fashion.

ANT

By utilizing ANT+ for group data collection, 2 to 3 observers/slaves are typically used to receive data from the 150 transmitters with less than one second delay in reception. The only limitation is the transmission range of the devices.

BLE

In the case of the typical Bluetooth Smart sensor requiring a connection, the observer would have to connect to each device, request the data, disconnect and repeat the process for the next device. If each sequence takes 250 ms on average to complete it would take over 35 seconds to hear from each sensor. To shorten this time period, multiple observes can be added to perform parallel operations. With three observers this latency can be dropped to around 10 seconds per sensor. This process is complicated by requirements for managing which observer will be requesting data from each sensor to prevent duplicate requests.

Real-Time Control of Multiple Devices

As connected devices become commonplace in our lives, there will be more devices receiving commands from display devices. This is frequently observed in the health and fitness market and is beginning to emerge in other areas as well. Areas like home automation with "smart" products. In the health and fitness market, control of fitness equipment is the latest requirement to emerge. For bike trainer's, control of the resistance of the equipment has manifested itself as providing virtual wind speed or simulated incline while following a course during a workout.

ANT

When a display device wants to send data to one of the sensors, it queues a message to be sent the next time the sensor sends its broadcast message. This allows a typical 8 channel ANT radio to have seven messages queued at any one time. Utilizing multiple radios the system can handle many messages in a parallel nature. The ANT+ FE-C profile from thisisant.com describes the typical use case for the monitoring and control of fitness equipment.
http://www.thisisant.com/developer/ant-plus/device-profiles/#525_tab

BLE

For BLE devices, the control of the equipment is performed via the connection interface. When the display device wants to send the equipment a command, it needs to establish a connection before it can send the control messages. In the group monitoring case there is an inherent fragility for the overall system when relying on BLE control connections to send messages to equipment. This fragility is introduced because the equipment can only have one BLE connection established at a time. If a participant in the class is able to establish a control connection to the equipment and proceeds to hold onto that connection, the group monitoring system will not be able to gain access to the control connection.

Data Collection Topologies

When using ultra-low power radios to collect data from sensors and equipment there are multiple variations of the physical spaces used when monitoring the data. The two extremes for the usage are high densities of radios in a confined space and low densities of radios across a distributed space. Each of the configurations poses challenges for the group monitoring solution. Both ANT and BLE are capable of being used in these environments, but there are inherent benefits to using ANT radios as opposed to BLE. Given both radio technologies use 2.4GHz RF there are some common characteristics that need to be understood about the interaction of the RF signal and water. The resonant frequency of water is 2.4GHz. This means water has a strong affinity to absorb the transmitted energy from the radio. For most of the sports and fitness applications discussed here, the sensor/radio combination is either worn on the body or is in close proximity of large numbers of people. Since the human body is about 65% water, it is very good at absorbing the transmissions from the radios used in these applications. The typical transmission distance can be cut in half when the body is placed between the transmitter and receiver, dramatically changing the effective radio communication range. The other environmental condition that can affect the effective range of the radios is humidity. Since humidity is the measure of water content in the air, a higher humidity level translates to shorter effective ranges for radio communication.

High Density

In the high-density radio environment, such as a group cycling class, there are a large number of radios in a confined space. This also implies there are a large number of people in the environment. With the high concentration of people, the transmission range for radio transmissions are considerably shorter than typically experienced. To solve the problem of many radios and shorter transmission range multiple receivers are needed to fully cover the space.

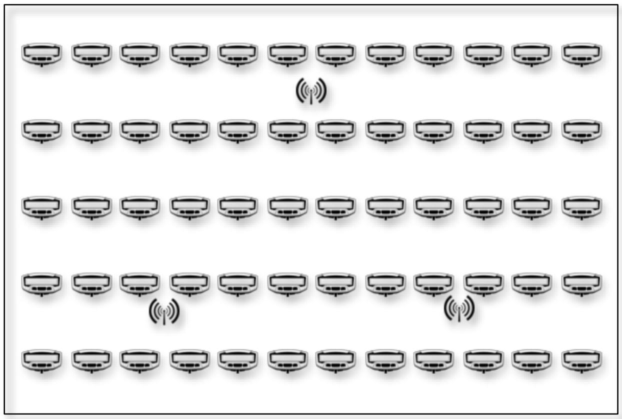

Figure 2: High Density Environment

ANT

When ANT radios are used in the high-density environment multiple receivers are employed to ensure complete coverage of the collection area. With ANT protocol, each receiver listens to all of the transmitters within range of the receiver. If more than one receiver hears from the same sensor the system receives duplicate packets. The application or driver decoding the ANT transmission is responsible for de-duplicating the packets before decoding the data. In this type of environment, the ANT protocol has been observed handling upwards of 150 radios when using three receivers distributed throughout the data collection area.

BLE

Unique challenges are faced when BLE is utilized in the high-density environment. With the traditional 4.0 implementation of the specification, a connection is needed to receive data from each piece of equipment in the space. For the extreme case of 150 radios, it could take 10 seconds to receive one piece of information from each device even when utilizing multiple radios to perform the communication. This is made easier if the communication relies entirely on data contained in the advertisement message without the need for a connection. This still does not solve the issue of being able to send control commands to each piece of equipment in a timely fashion. It also does not protect against a monitoring device monopolizing the control connection.

Distributed Area

In many cases a group data collection system will need to receive data from multiple devices distributed through a large area. This is the case for large gymnasiums, multiple rooms, or when outdoors. When using dispersed radios in this type of communication, the typical radio range of 10 to 20m is not sufficient when using a single receiver. In the case of the gymnasium and a chest based heart rate monitor, a person on one end of the gym facing away from the receiver will effectively disappear from the system. This occurs because their body is absorbing the signal. To solve this problem, placing two radios at both ends of the gymnasium provides an open line of sight between the transmitters and receivers. When multiple rooms are being used for a group activity, at least one receiver is placed in each space and the data collected by the receivers is forwarded to the monitoring application.

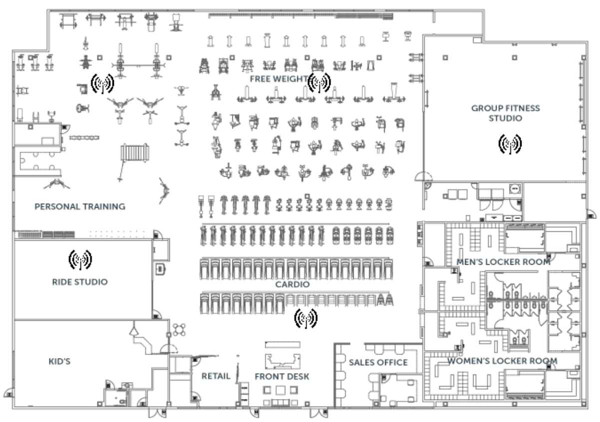

Figure 35: Distributed Collection Environment

ANT

With ANT radio topology, body worn sensors can move throughout the distributed collection area without data loss concerns. Because any number of receivers can be receiving data from the transmitters, overlapping collection zones are used to ensure there are no dead zones in the collection area. In addition to this, using Receive Signal Strength Indication (RSSI), between the transmitter and receiver radios, will help identify the correct placement of receivers. When control commands are needed, the system determines the best receiver to use for communication based on signal strength. As the transmitter moves throughout the collection area each command is routed to the appropriate receiver for sending data back to a device.

BLE

Bluetooth smart has some variations in operation with regard to the distributed environment. If a device is communicating its data via the advertisement packets and has no need for a connection, then the distributed data collection model is very straightforward and similar to the ANT solution. Since any of the distributed receivers can hear the advertisement packet, the BLE device can move throughout the environment without conflict or loss of transmission data provided there is a grid of receivers with overlapping coverage. All of the data from the advertisement packets is forwarded to the monitoring application for analysis.

However, if connections are required to either receive data or send commands, the system architecture becomes more challenging. Assuming no other BLE central devices take control of the connection, the system needs to manage which receiver is managing the connection. As the device moves throughout the environment the connection quality degrades because of increased distance to the receiver. When the connection quality degrades to the point of loss of connection the system must decide which receiver is the best to use to reestablish the connection. If radio resources are available on the new receiver, the system reconnects to the device. However, if the receiver is busy and does not have resources available, a new connection is not possible and the device will have to wait until resources are available to make the data connection.

Established Equipment Profiles

To achieve the lowest power operation possible and provide for interoperability between device manufacturers and display devices standardized profiles have been created. In order to utilize the data from sensors or equipment via a wireless interface, the data sent from the units using the transmission protocols needs to be decoded. The radio transmissions are optimized to operate at very low power so efficiency of transmission is of paramount concern. Without the combination of standardized profiles the adoption of new products into the marketplace is slowed because of interoperability problems. The lack of interoperability leads to increase development cost for incorporating devices into an ecosystem, through confusion about data types and units used to communicate similar types of information. Both ANT+ and BLE have standards committees responsible for maintaining the standards, but some profile standards are more fully developed than others. When standards to not exist developers are forced to create custom profiles without input from outside sources. This leads to proliferation of different implementations to accomplish a common task.

ANT

Devices supporting the ANT+ protocol need to be certified through the ANT+ certification process. Thisisant.com is the website to reference for all certification needs. The site is maintained by Dynastream and the certification process is supported by automated tools designers use to test out both sensor, equipment and display devices. A list of supported profiles can be found at http://www.thisisant.com/developer/ant-plus/device-profiles/.
Products desiring to use the ANT+ protocol and be listed as an interoperable product must be submitted to Dynastream for review and a fee paid to support the validation process.

Fitness Equipment Profile

The specific profile that is of particular interest for the Fitness Equipment (FE) manufactures and group-monitoring applications is the Fitness Equipment and Control profile. This profile was previously available exclusively to manufacturers utilizing the FIT1e module from Dynastream. With the advent of the Nordic Semiconductor nRF51 series SoC devices with integrated ARM processor and 2.4GHz radio, the profile has been made available for general use. This profile provides definition for many types of fitness equipment as well as a robust definition for bi-directional communications for supporting equipment control functions.

In 2015, an update to the profile was adopted to extend the protocol to allow easy access to the transmitted data for group monitoring solutions. The typical implementation of the FE protocol required pairing with a display device in order to start the transmission of data from the FE. With the update to the profile there is the option to enable an additional channel for broadcasting data to a monitoring system independent of an individual display device. This allows a room full of fitness equipment to send data to a group monitoring system without requiring each participant to have a device to initiate the broadcast.

BLE

Bluetooth Smart enabled devices need to be certified by the Bluetooth SIG in order to use the BLE protocols. The Bluetooth SIG maintains the profiles/protocols used for communicating information from the sensors or fitness equipment to the display devices. The current list of supported profiles listed on the Bluetooth SIG can be found here:
https://developer.bluetooth.org/gatt/profiles/Pages/ProfilesHome.aspx

Products desiring to use the Bluetooth Smart protocol must be registered with the Bluetooth SIG and pay a listing fee.

As of the time of publication of this paper there is no published standard for fitness equipment or any individual device for use in a group environment. There are a handful of products with proprietary services utilizing either connections or connectionless advertisements to support group-monitoring solutions. With the introduction of the 4.2 version of the BLE spec, devices are now allowed to continue to advertise when a connection has been established. Reference section 4.2.2.2 Advertising Procedure of the Core 4.2 spec for details. Expect ratified profiles for devices used for group consumption future releases of the BLE device profiles.

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