Study of ZiFi- A Zigbee Application

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ABSTRACT
WiFi networks have enjoyed an amazing penetration rate in recent years. However, due to the limited coverage, existing WiFi infrastructure only provides interrupted connectivity for mobile users. Once leaving the current network coverage, WiFi clients must actively discover new WiFi access points (APs), which wastes the precious energy of mobile devices. Although several solutions have been proposed to address this issue, they either require significant modifications to existing network infrastructures or rely on context information that is not available in unknown environments. In this review paper, a system called ZiFi is studied that utilizes ZigBee radios to identify the existence of WiFi networks through unique interference signatures generated by WiFi beacons. A new digital signal processing algorithm called Common Multiple Folding (CMF) is used that accurately amplifies periodic beacons in WiFi interference signals. ZiFi also adopts a constant false alarm rate (CFAR) detector that can minimize the false negative (FN) rate of WiFi beacon detection while satisfying the user-specified upper bound on false positive (FP) rate.

Keyword
Zigbee, Zi-fi (Zigbee-fidelity), Wi-Fi (Wireless fidelity), Digital Signal Processing, RSS (received signal strength)

1. INTRODUCTION
In recent years, 802.11-based wireless LANs, also known as WiFi networks, have enjoyed an unprecedent penetration rate. In particular, they are increasing deployed to provide Internet access in mobile environments. However, due to the limited coverage, existing WiFi infrastructure is only capable of providing intermittent connectivity for the users with high mobility. WiFi-enabled devices (e.g., laptops, PDAs, and smart phones) must actively discover new WiFi access points (APs) once they leave the coverage of current network. However, this approach wastes the precious energy of mobile devices due to excessive listening and scanning operations of WiFi network interface cards (NICs). Several solutions have been proposed to address the fore mentioned issue. The first approach utilizes a secondary low power radio that communicates with peer radios on WiFi APs to find connectivity opportunities or reduce the energy consumption of data transfers [2]. However, this approach requires significant modifications to existing network infrastructures. The second approach predicts the availability of WiFi based on context information. Cellular cell-tower information [11] or together with Bluetooth contact-patterns [10] have been used to improve WiFi prediction accuracy. However, such a context-aware approach requires extensive training based on historical information and hence is not feasible in unknown environments. In this paper, a system called ZiFi for discovering the availability of WiFi coverage for mobile users is studied. The design of ZiFi is motivated by the fact that low-power radios such as ZigBee and Bluetooth[17] often not only physically collocate with WiFi NICs but also share the same open radio frequency band with them. Leveraging the inter-platform interference caused by such coexistence, ZiFi enables ZigBee radios to identify the unique interference signatures generated by WiFi signals. As a result, a mobile device can use a ZigBee radio to detect the existence of WiFi APs in a purely passive manner, and only wakes up the WiFi NIC when WiFi connectivity is available. To capture WiFi interference signatures, ZiFi utilizes the received signal strength (RSS) indicator available on ZigBee-compliant radios. However, it is observed that the statistics of WiFi RSS samples, such as power magnitude[16][18], time duration, and inter-arrival gap, exhibit surprising resemblance with those of other RF sources, and hence provide little hint about the existence of WiFi. Motivated by this observation, ZiFi is designed to search for 802.11 beacon frames in RSS samples. Periodic beacon broadcasting is mandatory in WiFi infrastructure networks and hence provides a reliable means to indicate WiFi coverage. However, beacons are extremely scarce in normal WiFi traffic as hundreds of data frames are likely transmitted between two beacon instances. Without being able to decode incoming signals, finding beacon frames in RSS samples is like finding a needle in a haystack. To address this challenge, ZiFi adopts novel digital signal processing (DSP) and stochastic signal detection techniques to reliably identify the periodic interference patterns caused by WiFi beacon frames. The second approach predicts the availability of WiFi based on context information. Cellular cell-tower information [14] or together with Bluetooth contact-patterns [13] have been used to improve WiFi prediction accuracy. The approach of ZiFi to be increasingly feasible as more mobile devices are equipped with both low-power and high-power NICs that work in the same open radio spectrum. For instance, numerous ZigBee modules [6] have USB interface and hence can be easily connected to WiFi enabled laptops. Several cell phone vendors (e.g., Nokia and Pantech & Curitel) also provide smart phones [3] with built-in ZigBee interface or ZigBee modules [7] that can be connected to smart phones (e.g., through mini SD interface). ZiFi can also be easily implemented on other platforms (e.g., some Bluetooth radios [8]) that offer the RSS sampling interface. The implementation of ZiFi [1] involves:-

A novel DSP algorithm called Common Multiple Folding (CMF) that amplifies unknown periodic signals in RSS samples. A key advantage of CMF is that it can minimize the computational cost of processing unknown signals whose possible periods lie in a wide range. Then there was a constant false alarm rate (CFAR) detector that can minimize the false negative (FN) rate of classifying periodic signals as 802.11 beacons while satisfying the user-specified upper bound on false positive (FP) rate. An analytical framework that characterizes the detection performance of ZiFi by the FN and FP rates. It not only guide the selection of optimal detection thresholds for beacon detector but also allow to predict the opportunities of WiFi coverage based on empirically measured channel parametersImplementing ZiFi on two platforms, a Linux netbook integrating a TelosB mote through the USB interface, and a Nokia N73 smart phone [9] integrating a ZigBee card through the mini SD interface. Experiments on a test bed consisting of wireless routers, netbooks, smart phones, and TelosB motes shows , under typical settings. ZiFi can detect WiFi APs with high accuracy (< 5% total FP and FN rate), short delay (∼ 780 ms), and little computation overhead.

2. ZIFI ARCHITECTURE

ZiFi aims to utilize a ZigBee wake-up controller for mobile-phone or laptop users in order to save battery life, while constantly scanning for Wi-Fi access points. In essence, ZiFi represents the exact opposite goal from what is proposed in this paper. The driving force behind ZiFi is the constant drain that a Wi-Fi radio enacts on a mobile device during its active scanning period. In order to reduce this cost, a secondary low-power ZigBee radio is used to scan the frequency in order to determine the presence of Wi-Fi WAPs in the vicinity, and to wake up the Wi-Fi radio on the client device (typically a mobile phone or laptop). To capture Wi-Fi interference signatures, ZiFi utilizes the received signal strength (RSS) indicator available on ZigBee-compliant radios. However, we observed that the statistics of Wi-Fi RSS samples, such as power magnitude, time duration, and inter-arrival gap, exhibit surprising resemblance with those of other RF sources, and hence provide little hint about the existence of Wi-Fi. Motivated by this observation, ZiFi is designed to search for 802.11 beacon frames in RSS samples. Periodic beacon broadcasting is mandatory in Wi-Fi infrastructure networks and hence provides a reliable means to indicate Wi-Fi coverage [1]. Beacon broadcasting is the method that promotes Wi-Fi WAP discovery, wherein WAPs will release a periodic frame of a short duration containing a succinct homogeneous set of data. The energy signature created by beacon frames is easily spotted given a controlled environment. However, ZiFi operates in a lively RF environment, and as a result the algorithm used must be more robust to noise. ZiFi has the advantage that it may take longer for calculations as users are generally in a WAP's range for an extended period of time, allowing the algorithm to use more data and complex arithmetic operations. The false negative rate is not as crucial for this application, as a false negative in ZiFi represents a user missing the opportunity to utilize a Wi-Fi network; a false negative in the mesh network represents a potential survivor missing access to critical emergency information.The algorithm developed utilizes a special variation of folding to determine Wi-Fi activity with an error rate of below 4.8%[13]. The prototypes developed require additional hardware to be attached to the mobile phones or laptops, which increases power consumption and adds bulky external equipment. However, the goal is to extend this idea to a dedicated piece of hardware inside machines as a functional low-power wake up controller provided the transceiver can be integrated with current technologies.

2.1 High Level Design – Hardware

The design of the hardware is dependent upon two factors: whether or not the ZigBee module will also be used for communication, and whether or not the Wi-Fi sensing module will be implemented as a canned-up piece of hardware acting specifically as a wake-up controller, or as software on the client device

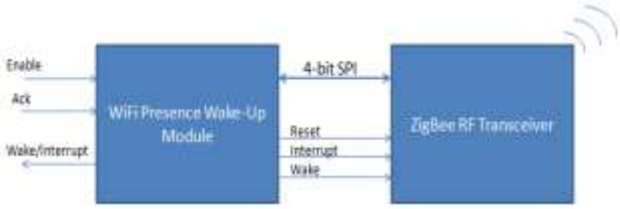

Figure 2.1 Hardware Specification for Wake-Up controller[1]

Figure 2.1 provides an example of how the hardware could be configured. This setup assumes that the microcontroller used for sensing Wi-Fi activity is separate from the application. It also allows for interrupt driven behavior to be modeled using the Interrupt/Ack ports. The enable bit allows for the entire wake-up controller to be asleep while the main system is in use, while the wake-up function would allow the controller to wake up the main system upon Wi-Fi discovery. This hardware specification also keeps the ZigBee Transceiver separate so that the main system may also communicate with it using the SPI interface, or let it sleep when unused as the wake-up time for the ZigBee module is approximately 15ms.

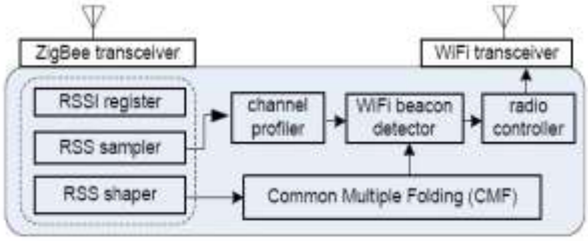

Figure 2.2 System Architecture of Zifi [1]

Fig 2.2 shows the system architecture of ZiFi. The RSS sampler reads the built-in received signal strength indicator (RSSI) register of ZigBee radio at a designated frequency. The RSS samples are then processed by a RSS shaper that adjusts the RSS values to mitigate noise (e.g., the data frames) in the beacon detection. The shaped RSS samples are then processed by the Common Multiple Folding (CMF) algorithm. CMF is a digital signal processing algorithm that amplifies the periodic signals in RSS samples. A key advantage of CMF is that it can minimize the cost of amplifying unknown signals whose possible periods lie in wide range. The amplified RSS samples are fed into a constant false alarm rate (CFAR) [1] beacon detector that classifies a periodic signal as genuine WiFi beacons if its amplitude exceeds a threshold. By adopting a theoretically derived threshold, the beacon detector can minimize the false negative (FN) rate while satisfying the user-specified upper bound on false positive (FP) rate. Finally, if WiFi beacons are detected, the radio controller turns on the WiFi NIC. It also present an analytical framework that models the FN and FP rates of beacon detection based on the utilization ratio of wireless channel. The utilization ratio is measured from RSS samples by the channel profiler. The analytical FN and FP models guide the selection of optimal detection thresholds for ZiFi's beacon detector. As discussed above, ZiFi utilizes energy sensing through the RSSI of ZigBee radio to detect the existence of WiFi APs. ZiFi can be easily implemented on other radio that provide the RSSI interface. For instance, a few existing Bluetooth provide RSSI although it isnot a mandatory feature in Bluetooth standard.

3. COMMON MULTIPLE FOLDING (CMF)

A novel algorithm called Common Multiple Folding (CMF) that can minimize the total number of additions required to fold on multiple periods. The design of CMF is based on the observation that the folding result of period P can be efficiently computed from that of period Q if Q is an integer multiple of P, i.e., Q mod P = 0. Formally, given folding result FQ, only Q − P additions are needed to obtain FP . In comparison, total N −P additions are needed to compute FP directly from original N RSS samples. For example, Fig. 3.4 illustrates that the folding result of period 6 can be calculated by an additional folding operation on the result of period 12. For instance, the first element in the folding result of period 6 can be computed by a single addition of the the first and seventh elements in the folding result of period 12, i.e., F6[1] = F12[1] + F12[7]. In total, 12 − 6 = 6 additions are required to fold on period 6 if the folding results of period 12 are already available. In comparison, total N − 6 additions would be needed if the folding is directly applied to the original RSS samples.

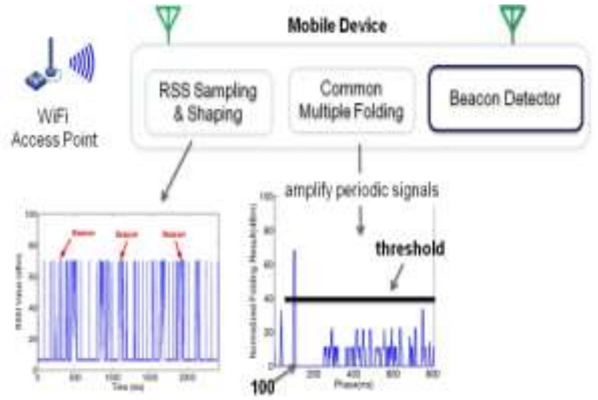

Figure 3.1.1 Common Multiple Folding [1]

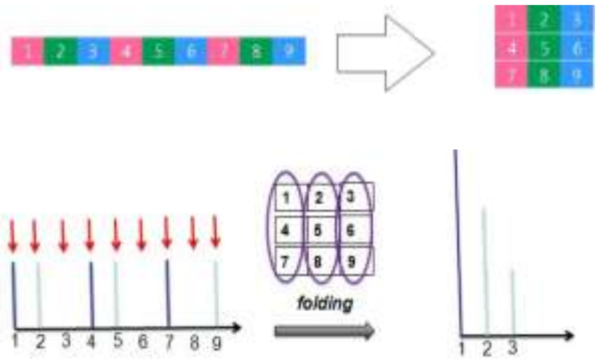

Figure 3.1.2 Folding

A promising approach to reducing the computational cost is to first fold on the LCM of all periods in P, and then reuse the results to fold on each of the periods. In order to maximize the utility of intermediate folding results, this idea can be applied recursively by partitioning P into subsets and folding on the LCM of all periods in each subset. This process can be naturally encoded by a tree where a node represents a period set and its LCM and all children of the node constitute the partition of the set. Such a tree is referred as CMF tree. Fig. 3.2.1 shows two CMF trees that differ in how to partition the period set at each node. Some important points:

• Building a tree based on the folding
• Fold based on Least Common Multiplier (LCM)
•In order to maximize the utility of intermediate folding results, folding can be applied recursively by partitioning the result into subsets and folding on the LCM of all periods in each subset

For example, Total N RSSI samples, first fold onto 2520 period

3.2 CMF Tree

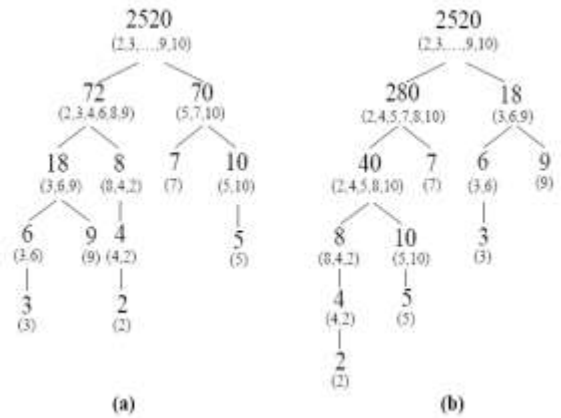

Fig: 3.2.1 CMF Tree [1]

In above figure, two CMF trees are shown as:
The left tree
• N - 2520
2520 – 72
2520 – 70
72 – 18
72 – 8
….
= N +2654 additions
• The right tree
N + 2832 additions

Always better to choose two LCM factors with a min difference.

3.3 CFAR Detector

CFAR is a constant false alarm rate detector that performs the following tasks:

- Consumes the result from the CMF operation
- Calculates the threshold value based on utilization
- Detects the False Positives
- Identifies significant pulses as beacons

4. HIGH LEVEL DESIGN – SOFTWARE

The software, then, is dependent upon how the hardware is specified, and whether or not the controller should act in an interrupt manner, or as a constantly updating value. The basic discovery algorithm is platform independent, and requires only the RSSI stream sent from the ZigBee transceiver. It is assumed for this instance that the sensing module is a separate entity, and it has full control of the RF Transceiver. The behavior of the output bits is dependent upon the platform; therefore, for this instance, we will assume a one bit input that is active high once Wi-Fi activity is determined.

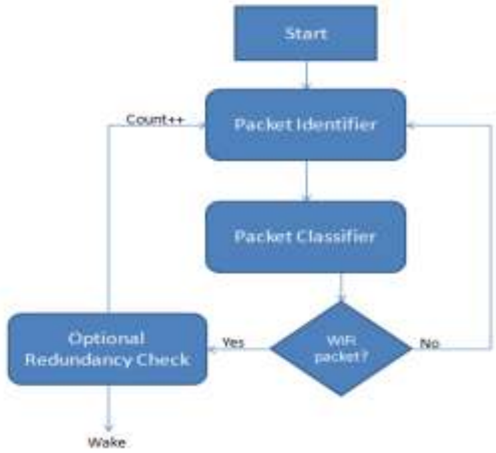

Figure 4.1 High Level Algorithm Specification[1]

The two main functions within this algorithm are the packet identifier method and the packet classifier method. These two methods take as input the RSSI data stream from the ZigBee module, transforming it into a recognizable data structure that is then classified according to the a priori clustering algorithm defined by the user; finally a determination is made on whether the packet is a Wi-Fi packet, a Bluetooth packet, a ZigBee packet, or noise. If the packet is determined to be a Wi-Fi packet, an optional redundancy check can be used to increase accuracy, but at the cost of speed and possibly causing a false negative result. This optional redundancy check can be defined by the user based on the parameters that are trying to be optimized. ZigBee communication generally occurs on a specific subset of channels in order to avoid the peaks created by Wi-Fi interference[19]. However, if one were to attempt to sense active Wi-Fi access points or users searching for Wi-Fi access, one would instead listen on ZigBee channels correlated most closely with the peaks of Wi-Fi channels 1, 6, and 11. ZigBee channels 12, 18, and 25 would need to be scanned periodically to check for wireless activity. A lack of activity on these channels indicates that there is likely no Wi-Fi presence in the area[15]. However, activity on these channels does not necessitate that there is an active WAP or user searching for Wi-Fi access. Other sources of noise (e.g. microwave radiation, Bluetooth, and other ZigBee components) can emit waves in this frequency, causing a false positive during which it would be a waste of scavenged energy to turn on the Wi-Fi antenna. As a result, cluster analysis was chosen to determine within a relative accuracy whether a given signal belongs to Wi-Fi or to some other signal or noise in the same frequency band.

5. ADVANTAGES

5.1 Advantages of ZiFi over WiFi

Due to the limited coverage, existing WiFi infrastructure is only capable of providing intermittent connectivity for the users with high mobility. WiFi-enabled devices (e.g., laptops, PDAs, and smart phones) must actively discover new WiFi access points (APs) once they leave the coverage of current network. However, this approach wastes the precious energy of mobile devices due to excessive listening and scanning operations of WiFi network interface cards (NICs). On the other hand the approach of ZiFi to be increasingly feasible as more mobile devices are equipped with both low-power and high-power NICs that work in the same open radio spectrum. For instance, numerous ZigBee modules have USB interface and hence can be easily connected to WiFi enabled laptops. ZiFi has following advantages:-

- Low cost
- Low power consumption
- Scalability
- Reliability
- Supports large number of nodes
- Easy to deploy
- Very long battery life
- Secure

Figure 5.1 Zigbee & WiFi

6. CONCLUSION

WiFi scan can cause a waste of energy, if the WiFi interface gets to know the existence of the signal, we can save energy. ZiFi tried to achieve this through RSSI sampling and extracting the beacon information**.** In this paper it is studied that ZiFi utilizes ZigBee radio to identify the existence of WiFi networks, Common Multiple Folding (CMF) amplifies signals with unknown periods in WiFi interference samples. ZiFi adopts a constant false alarm rate (CFAR) detector that can minimize the false negative (FN) rate of WiFi to improving stochastic detection performance. So The use of ZiFi not only reduces the power consumption but also provide a long battery life to the device. As the set up cost is low so it is easy to deploy and large number of nodes are supported. Hence it can be reviewed that it is reliable and secure technology that can solve the problem of wastage of energy to great extent.

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