

Measurements of Multicast Service Discovery in a Campus Wireless Network

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Abstract—Applications utilizing multicast service discovery protocols, such as iTunes, have become increasingly popular. However, multicast service discovery protocols are considered to generate network traffic overhead, especially in a wireless network. Therefore, it becomes important to evaluate the traffic and overhead caused by multicast service discovery packets in real-world networks. We measure and analyze the traffic of one of the mostly deployed multicast service discovery protocols, multicast DNS (mDNS) service discovery, in a campus wireless network that forms a single multicast domain of large users. We also analyze different service discovery models in terms of packet overhead and service discovery delay under different network sizes and churn rates. Our measurement shows that mDNS traffic consumes about 13 percent of the total bandwidth.

I. INTRODUCTION

Wireless networks and mobile devices that are WiFi-enabled are becoming more and more common. For the users of wireless devices to be able to find peer services, service discovery protocols are needed. Multicast DNS (mDNS) service discovery is among the most widely deployed service discovery protocols. One of the most popular applications that use mDNS is iTunes, which allows users to browse playlists of other iTunes users in the same subnet.

However, with the increasing popularity of applications that use mDNS, such as iTunes, mDNS traffic is considered to generate packet overhead. Such overhead may especially be seen on college campuses, where wireless networks are almost pervasive and a large number of wireless users are able to work on the same subnet. Furthermore, this packet overhead consumes network resources. Because of the packet overhead of mDNS traffic, the Office of Information Technology at Princeton University filters mDNS packets [1].

However, no formal measurement and analysis of the overhead of multicast service discovery traffic in a campus wireless network currently exists. We have not been able to find measurements and analysis of multicast traffic, even though many multicast protocols have been proposed during the past few decades. There have not been any popular applications using multicast protocols. But now, applications that use mDNS are immensely popular, especially on college campuses, so it is worthwhile to measure and analyze mDNS traffic.

This paper analyzes the packet overhead of mDNS traffic in a typical college wireless network to show how much mDNS generates packet overhead. We show the bandwidth usage of mDNS packets and the effect of multiple APs on the same channel of multicast packets in a Columbia University's wire-

less network. We analyze different service discovery models in terms of packet overhead and service discovery delay under different network sizes and churn rates.

In Section II, we discuss the overview of multicast service discovery. Section III describes how our measurement was set up. Section IV outlines our findings about mDNS traffic in a campus environment, in terms of the number of packets and their impact on wireless traffic. In section V, we analyze different service discovery models. Finally, we describe related work in section VI.

II. MULTICAST SERVICE DISCOVERY BASICS

There are two protocols for host naming on a local network without a central DNS server: Multicast DNS (mDNS)[2] and Link-local Multicast Name Resolution (LLMNR) [3]. LLMNR is currently implemented only in Windows Vista and Windows CE, but mDNS is implemented on Windows, Linux and Mac OS, and has been successfully ported to other POSIX platforms and Java-based platforms [4] as well. Multicast DNS enables the translation between a local host name and IP address without a central DNS server. This local host name selected by each device is meaningful only on the local network. Multicast DNS service discovery [5] allows users to announce their services and discover peer services. The service discovery protocol uses three record types: PTR, SRV and TXT record. The PTR record is used to discover service instances on the local network. The SRV record provides port number and IP addresses of the services. The TXT record provides additional information about services.

III. MEASUREMENT SETUP

Since Columbia University's wireless network (IEEE 802.11 b/g) is composed of single subnet and mDNS works within single subnet, all mDNS packets are transmitted to all the wireless users who use mDNS in the campus. We use two sniffing tools, mDNSNetMonitor and Wireshark 0.99.6 [6], to measure mDNS traffic in this network. Apple provides mDNSNetMonitor along with the Bonjour source code to record the patterns of mDNS protocol usage. We use Wireshark to analyze the raw mDNS packets and other multicast packets to obtain more details.

Each measurement lasts for two minutes. We selected a measurement time from 2 PM to 5 PM which is the busiest time of user activity on campus. The machine we used for sniffing has 1 GB of RAM and a 1.66 GHz Core 2 CPU running

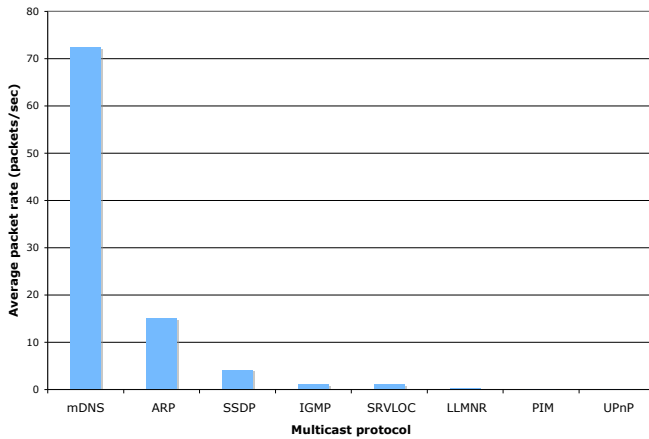


Fig. 1. Multicast packets

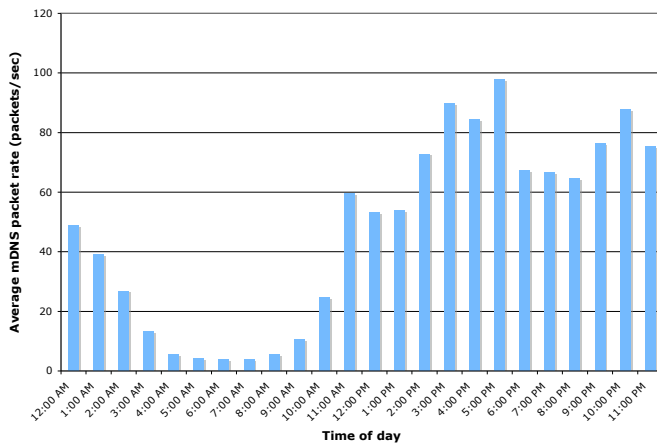


Fig. 2. The average mDNS packet rate on a weekday

Linux. The PCMCIA wireless card used for sniffing is a Orinoco 11a/b/g card with the Atheros chipset. We used the network card interface in a monitoring mode to capture all packets over-the-air.

IV. MDNS IN A CAMPUS WIRELESS NETWORK

Fig. 1 shows the average multicast packet rate categorized by multicast protocols. It shows that the majority of multicast packets in the network are mDNS packets. LLMNR packets take a very small portion of multicast packets. The figure also shows that there are other service discovery protocols (SRVLOC, SSDP and UPnP), but the number of those service discovery packets is very small. Therefore, we will mainly focus on mDNS. We also measure the number of ARP packets since ARP packets are one of the most popular broadcast packets in the network. As we can see, the number of mDNS packets was much higher than that of ARP packets.

A. Number of mDNS packets

Fig. 2 shows the average mDNS packet rate on a weekday. The times of 2 PM-6 PM and 9 PM-11 PM are the busiest times of day when users use applications that use mDNS. Fig. 3

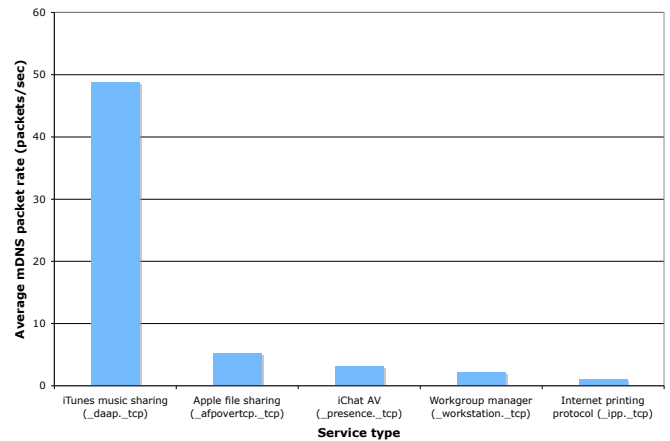


Fig. 3. The average mDNS packet rate by service types

TABLE I
AVERAGE NUMBER OF MDNS USERS SEEN IN NETWORKS DURING MEASUREMENT WHEN THE TOTAL OF 944 USERS ARE SEEN IN THE NETWORK

Service type	number of users
iTunes music sharing (_daap._tcp)	188
Apple file sharing (_afpovertcp._tcp)	83
iChat AV (_presence._tcp)	25
Workgroup manager (_workstation._tcp)	49
Internet printing protocol (_ipp._tcp)	16

shows the average mDNS packet rate by service type. We show the five major applications based on the number of mDNS packets. It shows that the majority of mDNS packets are generated by the iTunes (_daap._tcp) application. Table I shows the average number of users seen on the networks during the measurement. As we can see in the table, the number of iTunes users is the largest. In service resolution process of iTunes, iTunes sends SRV and TXT query records to all iTunes users, and responds with SRV and TXT records. This service resolution process generates many mDNS packets. In other applications, even though the process of querying and responding for SRV and TXT record processing exists, the process is rarely performed since users do not actively use the application.

B. Busyness ratio of mDNS packets on wireless networks

On the uplinks of mDNS packets, the transmission is performed from a station to an AP, so the transmission to an AP is unicast. However, on the downlinks of mDNS packets, the transmission is performed from an AP to many multicast users, so the transmission is multicast. Therefore, all the uplink transmission rates depend on the users' network interfaces. Since most users use laptop computers with IEEE 802.11g wireless cards, most of the uplink transmission follows IEEE 802.11g. However, the downlink transmission rate is fixed to 11 Mb/s since in a Columbia University's wireless network, an AP has to match the transmission rate with the lowest maximum transmission rate between IEEE 802.11g and b even though most users use a IEEE 802.11g wireless card.

The maximum transmission rates are 54 Mb/s and 11 Mb/s for IEEE 802.11 g and b, respectively. We calculate the bandwidth usage of mDNS packets by the busyness ratio, B .

The busyness ratio, B , is the ratio of the sum of all the busy periods of mDNS packets to U .

$$B = \frac{T_D + T_U}{U},$$

where T_D and T_U are the total downlink and uplink transmission time of mDNS packets per unit time including all overhead. The receiver can synchronize the incoming signal by the physical layer convergence protocol (PLCP) preamble before receiving actual data, and the header provides information of the frame [7]. Therefore, we include the PLCP for performance measurement. The downlink transmission time, T_D , is

$$T_D = (T_{DIFS} + T_d) \times N_d$$

$$T_d = \frac{L_m}{R_d} + T_{PLCP},$$

where T_{DIFS} is the time length of DIFS, T_d is the transmission time of a mDNS downlink packet, and N_d is the average number of mDNS downlink packet in unit time. L_m is the average mDNS packet size including MAC layer header, R_d is the downlink transmission rate, and T_{PLCP} is the time length of the PLCP preamble and header. Table II shows the parameters of IEEE 802.11 b/g.

The uplink transmission time, T_U , is

$$T_U = (T_{DIFS} + T_{SIFS} + T_u + T_{ACK}) \times N_u$$

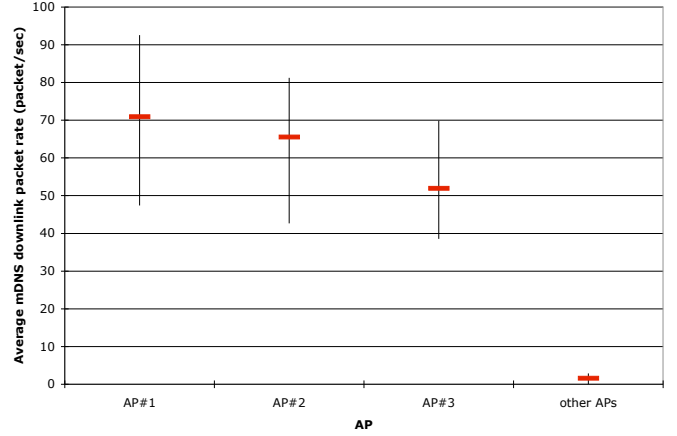
$$T_u = \frac{L_m}{R_u} + T_{PLCP}$$

$$T_{ACK} = \frac{L_c}{R_c} + T_{PLCP},$$

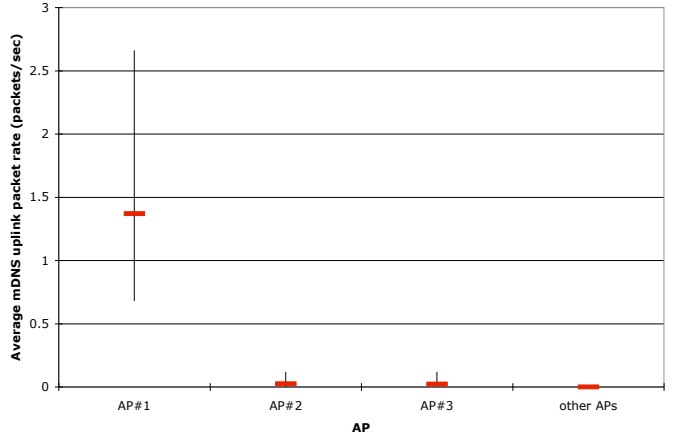
TABLE II
PARAMETERS IN IEEE 802.11 B/G

Parameters	Size (bits)	Tx rate (Mb/s)	Tx time (μ s)
PLCP Preamble	144	1	144
PLCP Header	48	1	48
SIFS	-	-	10
DIFS	-	-	50
ACK	112	R_c	$112/R_c$

where T_{SIFS} is the time length of SIFS, T_u is the transmission time of the mDNS uplink packets, and N_u is the average number of mDNS uplink packet in unit time. R_u is the uplink transmission rate. T_{ACK} is the transmission time of control frames, ACK. L_c is the length of control frames, ACK. R_c is the transmission rate of ACK. At Columbia University, we have defined that transmission rates of ACK from APs to be the same as data transmission rates from users.



(a) Average rate of mDNS downlink packets associated to co-channel APs



(b) Average rate of mDNS uplink packets associated to co-channel APs

Fig. 4. Average rate of mDNS packets associated to co-channel APs

C. The effect of multiple APs on the same channel

Since several APs are installed on the same radio channel, the co-channel APs transmit the same multicast packet to the same channel. Therefore, even though a receiver receives packets from an associated AP, packets from all co-channel APs consume bandwidth at the receiver. Fig. 4(a) and Fig. 4(b) represent the average rate (with maximum and minimum rate) of the captured mDNS downlink and uplink packets at several APs. As we can see, the same multicast packets from several APs (mostly three APs in our measurement) are captured in the local area. When we calculate the busyness ratio, B , we should consider this co-channel effect. Therefore, the average rate of mDNS downlink and uplink packets is the sum of all downlink and uplink packets from the co-channel APs. The values of N_d and N_u are 190 packets and 1.4 packets, respectively. The reason for the difference between the two values is that on the downlinks, the packets come from all users in the campus wireless network, but on the uplinks, the packets come only from the users in the small local area. In our measurement, L_m is 578 bytes. Therefore, busyness ratio, B is 0.13. Since other packets cannot be transmitted during the transmission

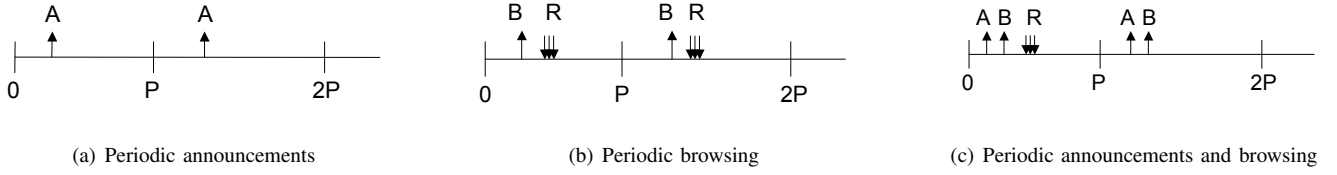


Fig. 5. The service announcements and browsing models (A: service announcements, B: service browsing, R: responding, P: period)

of mDNS packets, we can say that mDNS traffic consumes 13 percent of the total bandwidth.

If we do not consider the co-channel effect (i.e., consider the packets associated to AP#1), the value of N_d and N_u are 70.9 packets and 1.3 packets, respectively. Therefore, the busyness ratio, B is 0.05. Therefore, the effect of mDNS packets for bandwidth usage varies depending on the number of APs on a channel.

V. COMPARISON OF SERVICE DISCOVERY MODELS

To see the trade-offs of different service discovery models in terms of packet overhead and service discovery delay under different network sizes and churn rates, we analyze three different service discovery models: periodic announcements, periodic browsing, periodic announcements and browsing. We do not consider co-channel effects since the number of co-channel APs and the signal strength of the APs could vary in different places. We do not consider the service resolution processes (i.e., querying and responding for SRV and TXT records) since these service resolution processes depend on the application and user behavior. We do not consider the mechanisms used in mDNS protocol to reduce packets, such as aggregation of several answers in a packet. Therefore, the models in this analysis are different from multicast DNS service discovery protocol. The objective of this analysis is to compare different service discovery models under different network sizes and churn rates.

We assume that users join with Poisson distribution with rate λ . We assume that the service announce, browse and response packets are transmitted by multicast. The average number of users in the network is N and the average number of users associated to an AP is N_a . The service announce and browse period is P .

A. Model A: Periodic announcements

Fig. 5(a) shows the periodic announcements model. In this model, users discover services only by the periodic announcements (A) of other users. Therefore, there is no response packet. On the uplinks, N_a users associated to an AP send announce packets. On the downlinks, the AP transmits service announce packets from all N users.

B. Model B: Periodic browsing

Fig. 5(b) shows the periodic browsing model. In this model, users discover services by periodic browsing (B) and the response to the browse of others. On the uplinks, N_a users browse a service and they respond to the browse of N users.

On the downlinks, the AP transmits the service browse packets from all N users and response packets for every browse packet.

C. Model C: Periodic announcements and browsing

Fig. 5(c) shows the periodic announcements and browsing model. In this model, users discover services by periodic announcements (A) and periodic browsing (B) of services. The response packets are transmitted only when a new node joins the network and browses services. After initially responding to the service browsing of new nodes, users do not send response packets for the service browsing until other new nodes join the network. The number of response packets depends on the arrival rate of new nodes, λ .

D. Comparison of models

We define the churn rate, r , as $\frac{\lambda}{N}$. From Little's law, $N = \lambda T$ where T is the average lifetime users spend in the network, we can calculate the arrival rate, λ , given the average number (N) of users in the network and their average lifetime (T) in the network. We vary the lifetime of users from 10 minutes to 1 hour (i.e., vary the churn rate from 1/600 to 1/3600). We vary the average number of users in the network from 100 to 500. We assume that the average number of users associated to an AP is 10. Fig. 6 shows the average service discovery packet rate of three different models when the period (P) is 30 minutes. As we can see in this figure, model A generates the lowest number of service discovery packets. In model A, the average rate of service discovery packets increases slightly as N increases. However, since the difference between the value of rate in model A and the values of rate in other models are large, so the graph of model A looks flat. The service discovery delay of model A is the highest since the service discovery only depends on the announcements from users. The worst case of the service delay of model A is P . The delay of the two other models can be ignored since users immediately respond to the service browsing of newly joined nodes. The number of service discovery in model C depends on the lifetime of users. In high churn rate, where the lifetime is 10 minutes, the number of service discovery packets is the largest. When we compare model B and model C (which has lifetime of 30 minutes), the result is almost the same. In model C, a new node joins the network every 30 minutes, and in model B, the browsing period is 30 minutes. Therefore, the result is the same.

TABLE III
THE NUMBER OF SERVICE DISCOVERY PACKETS WITH DIFFERENT MODELS

Models	Types of uplink packets			Types of downlink packets		
	Announce	Browse	Response	Announce	Browse	Response
Model A	$N_a \frac{1}{P}$	0	0	$N \frac{1}{P}$	0	0
Model B	0	$N_a \frac{1}{P}$	$(N_a - 1)N_a \frac{1}{P} + N_a(N - N_a) \frac{1}{P}$	0	$N \frac{1}{P}$	$(N - 1)N \frac{1}{P}$
Model C	$N_a \frac{1}{P}$	$N_a \frac{1}{P}$	$(N_a - 1) \frac{N_a}{N} \lambda + N_a \frac{N - N_a}{N} \lambda$	$N \frac{1}{P}$	$N \frac{1}{P}$	$(N - 1) \frac{N_a}{N} \lambda + (N - 1) \frac{N - N_a}{N} \lambda$

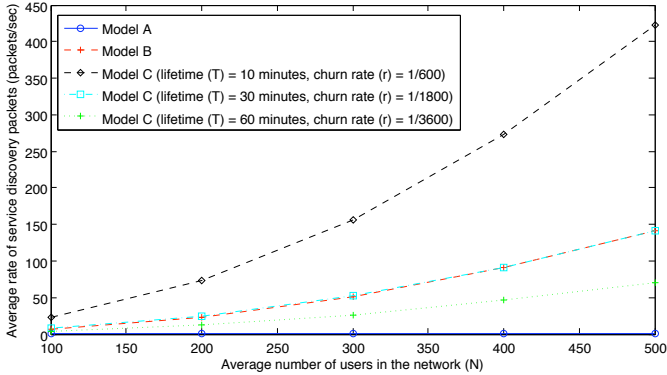


Fig. 6. The average service discovery packet rate of model A, B and C when period (P) is 30 minutes

VI. RELATED WORK

There are many papers that present the measurement and analysis of network packets in large area wireless networks [8] [9] [10]. However, their main considerations are network traffic pattern and user behavior in the networks. They do not analyze mDNS and multicast packets. Handerson et. al [11] present the characteristic of wireless network traffic by applications, including iTunes, but this paper does not show the details of iTunes, which uses the mDNS protocol.

Our previous work [12] presents the delay and service loss probability of service discovery in ad-hoc Zero Configuration Networking, but it does not show the measurement and analysis of service discovery packet overhead.

Furthermore, there are no papers at present which perform the measurement and analysis of mDNS packet overhead in a campus wireless network. Therefore, as far as we are aware, this paper is the first paper which focuses on the measurement and analysis of mDNS packet overhead.

VII. CONCLUSION

mDNS uses multicast, so it is considered to generate a lot of packet overhead and consume network resources, especially in a campus networks. However, there has been no formal measurement of mDNS in large wireless networks, so we do not really know how much packet overhead mDNS generates.

We showed the overhead (bandwidth usage) of mDNS packets by measurements. We analyze three different service discovery models: periodic announcements, periodic browsing, and periodic announcements and browsing models. The analysis shows the number of service discovery packets of

different models under different network sizes and churn rates. Our measurement shows that the current overhead of mDNS packets is not severe as mDNS traffic consumes 13 percent of the total bandwidth. In congested networks, such as those at IETF meetings or conferences, this overhead can have adverse effect on the performance of other network services. Furthermore, this consumption of bandwidth is mostly due to one popular application, iTunes, as about 69 percent of mDNS packets are iTunes packets. This means that if there are other popular applications which work in a manner similar to iTunes, or if the number of users using iTunes increases, the overhead of mDNS traffic will increase even more.

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