Defeating Internet attacks and Spam using “disposable” Mobile IPv6 home addresses

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Abstract—We propose a model of operation for next generation wireless Internet, in which a mobile host has hundreds of “disposable” Mobile IPv6 home addresses. Each correspondent is distributed a different disposable home address. If attacked on a given home address, the mobile user can block packets to that address and become unreachable to the attacker. Blocking one address does not affect other addresses. Other correspondents can still reach the mobile host. A new home address can also be requested via e-mail, instant messaging, or directly from the target host using a protocol that we develop. This model is especially useful against battery exhausting Denial-of-Service (DoS) attacks and CPU exhausting distributed DoS attacks, since it seems to be the only viable solution, currently. We show however that this model can also be used to defeat other attacks and also to stop spam.

I. INTRODUCTION

In the next generation Internet, it is estimated that billions of hand-held IP-addressable mobile phones will be directly connected to the wireless edges of the Internet, obsoleting today’s cellular telephony architectures. These devices will be equipped with VoIP (Voice over IP) software and standard IP applications e.g. Web browsing, instant messaging, file transfer etc. Users will enjoy constant wireless Internet connection regardless of their location i.e., not only in hotspots, but also in urban and rural areas.

In order to support such a large number of Internet hosts (mostly wireless and mobile) the next generation internet protocol, i.e., the IETF (Internet Engineering Task Force) standard IPv6 which provides 128-bit addresses will probably be used. A mobility management solution will also be needed to help mobile hosts receive packets regardless of their location i.e. current subnet. The IETF standard Mobile IPv6 (MIPv6) which provides 128-bit addresses will probably be used. A mobility management solution will also be needed to help mobile hosts receive packets regardless of their location i.e. current subnet. The IETF standard Mobile IPv6 (MIPv6) which provides 128-bit addresses will probably be used.

In MIPv6, the mobility is handled at the IP layer. Mobile hosts are IP-addressable and are constantly connected to the Internet. The Internet is, however, a hostile environment where malicious parties can easily eavesdrop voice and data traffic, impersonate other users, mount Denial-of-Service (DoS) attacks, infect them with viruses and worms and mount other attacks. Encryption and authentication solutions are available to defeat eavesdroppers and impersonators, however DoS attacks are particularly difficult to cope with since the Internet was designed to route any packet to its destination. Malicious packets can be sent to a destination in order to consume its resources, e.g. energy and CPU cycles. These attacks that we call battery/CPU exhaustion attacks will be particularly important as far as mobile users are concerned, since mobile hosts are battery-powered and their CPU power is limited. Attackers may also exploit buggy code to obtain unauthorized access or degrade performance, or infect victim hosts with viruses and worms, etc. Finally, SPam over IP Telephony (SPIT) will also be a potential problem in next generation Internet.

In this paper, we propose a solution to these attacks. Our proposal is called disposable home addresses (see next section for a review of Mobile IPv6) and inspired from the disposable phone numbers and e-mail addresses that are in use today. In our proposal, MIPv6 home addresses are used as phone numbers. A mobile user distributes a different disposable home address to each of their correspondents. If attacked on one of the home addresses, the compromised address is canceled, i.e. disposed of. Other correspondents that were distributed other home addresses are not affected. They can still reach the mobile host. New disposable home addresses can be remotely requested by e-mail or instant messaging, however, we also develop a protocol for directly requesting a disposable home addresses form the target mobile host. This model is especially useful against battery exhausting DoS attacks and CPU exhausting distributed DoS attacks, since it seems to be the only viable solution, currently. We show however that this model can also be used to defeat other attacks and also to stop spam.

The rest of this paper is organized as follows: Section III describes the problem that we address in this paper. Section IV describes the disposable home address solution that we propose, Section V proposes a protocol for distributing home addresses, Section VI proposes a solution to the same problem without assuming the existence of a Public Key Infrastructure (PKI), Section VII proposes a solution to the SPIT (SPam over IP Telephony) problem. Sections VIII, IX and X provide discussions of some architectural considerations, some limitations of our proposal and implementation considerations and finally Sections XI and XII present related work and conclusions.

II. MOBILE IPv6

The Mobile IPv6 (MIPv6) model of operation is illustrated in Figure 1. In MIPv6, a mobile host is assigned two IP addresses. The first one is called a home address (hoa). It is a
fixed address that points to the mobile host’s *home network*, where a special router called *home agent* serves the mobile host. When away from home, each time a mobile host visits a new subnet, it configures a new address called a *care-of-address* (coa). The mobile host then sends a *binding update* message to its home agent reporting its current care-of-address. Consequently, the home agent always knows the current IP address of the mobile host.

When a correspondent node needs to establish a session with the mobile host, it sends a packet to the mobile host’s fixed address which is the home address. This packet is intercepted by the home agent and tunneled to the mobile host’s current care-of-address. Upon receipt of the packet, the mobile host decapsulates the packet and obtains the original packet sent by the correspondent node. The mobile host has now the IP address of the correspondent node and sends a binding update message to the correspondent node. The correspondent node consequently learns the current IP address of the mobile host and the two hosts can communicate directly without the help of the home agent. This optimization is called *route optimization* or *triangular routing*. An alternative mode of operation is called *bidirectional tunneling*, in which a binding update is not send to the correspondent node. The mobile hosts’s reply is reverse tunneled back to the home agent which decapsulates the packet and sends it to correspondent node. This packet’s source address is the mobile host’s home address. This mode of operation is generally preferred for location privacy. The location i.e. current care-of-address of the mobile host is hidden from the correspondent node.

**III. PROBLEM STATEMENT**

In this section, we present several Internet attacks that can be mounted against next generation mobile hosts. We especially focus our attention on battery/CPU exhaustion attacks since currently disposable home addresses seem to be the only defense against these attacks. However, other types of Internet attacks e.g. port scanning, attacks that exploit buggy code, spam or any future attack that we cannot foresee can also be defeated using the proposed solution.

By current practice, it is assumed that a higher-layer identifier e.g. a *Fully Qualified Domain Name* (FQDN) or if (Session Initiation Protocol) is used, a SIP URI (Uniform Resource Locator) will be resolved to a home address and the destination mobile host will be reachable at that address. Consequently, an attacker who learned these identifiers can mount attacks against the obtained home address.

One solution to these threats is to keep these higher-layer identifiers secret and not sending them in clear-text over the Internet (the latter being a pre-caution against eavesdroppers). We feel however uncomfortable with this approach. Mobile host identifiers need to be shared for communication and we believe that they may easily leak to the hands of malicious users and attackers.

**A. Battery exhaustion attacks**

In wireless communications, energy is a scarce resource since terminals are battery powered. Most link-layer wireless access protocols support a mode called *dormant mode*, or *power save mode* in which the network interface consumes much less energy. In this mode, the receiver circuits are mostly off, and they are periodically switched on to check if a packet was received while the terminal was in dormant mode, and buffered by the access point or base station. This optimization is very important because listening consumes an important amount of energy and terminals are idle (i.e. not sending or receiving) most of the time. Transmitting consumes even more energy, and in power save mode, terminals do not transmit frames.

In cellular access technologies, dormant mode is possible in a much larger area than a single cell. Cells are grouped into paging areas, i.e., each *paging area* contains a large number of cells and covers a large geographical area. When moving within paging area boundaries, a terminal remains in dormant mode and does not report its exact location (cell) to the network and conserves energy. When there is an incoming call, however, the network needs to page the terminal in its current paging area. This is achieved by broadcasting a *paging message* in all cells of the paging area. The terminal then wakes up, reports its exact location and the call is delivered.

An attacker (located anywhere in the Internet) who learned the home address of a mobile host, can mount a DoS attack by continuously sending packets to that address. This attack would consume the energy of the target mobile host by preventing it from entering power save mode and forcing it to send reply packets (and possibly link-layer ACKs returned to the leaf router or access point). This is a fundamentally difficult problem. It needs addressing because an important source of energy consumption in a battery powered mobile device is the network interface. Note that the energy consumption problem here is two-fold:

- Victim is deprived from sleep mode (network interface)
- Victim is forced to transmit reply packets (link-layer ACKs and upper layer reply packets e.g. TCP SYN/ACK, or SIP OK)

It can be noted that two kinds of attacks are possible. In the first one, the attacker may only want to deprive the victim from power save mode. Let \( T \) the time duration a victim...
waits before entering sleep mode when it is not in active communication. The victim can be deprived from sleep mode by sending $1/T$ packets per second. In the second attack, the attacker can send more frequent packets and force the victim to send reply packets and consume more energy in addition to sleep mode deprivation. In this paper, we assume the second type of attack. The attacker sends as much packets as possible in order to exhaust the victim’s battery. If the attack succeeds, the device may become completely unavailable until its battery is recharged. The user who may not have foreseen such premature battery outage may not have their charger with them, or a place to recharge the battery may not be immediately available.

Experiments showed that an infrastructure mode 802.11 equipped HTC mobile phone’s energy (full battery, 1350 mAh) can be consumed in $\sim 3.5 - 4$ hours by continuously sending it ICMP echo request (ping) packets. Under normal conditions, i.e. without attack, the phone survives $\sim 1$ day without recharging (802.11 activated but idle). Note also that the attacked phone’s battery was full. The attack may shut down a target mobile device much more quickly if its battery level is low. Attackers can probably obtain better results against outdoor technologies. Cellular terminals usually have larger distances to the base stations, requiring more power to overcome low signal-to-noise ratio. I.e., replies to malicious packet will need to be transmitted at a higher power, consuming the victim’s battery more quickly.

Note that a simple solution e.g. filtering the attacker’s IP address would not work because the attacker can randomly spoof source IP addresses. End-to-end authentication solutions (e.g. IPsec[6]) also do not solve this problem, since the packet is dropped by the target, which is too late. Energy is consumed for receiving the packet, possibly generating a link-layer ACK, and the target is deprived from link-layer power save mode since it is continuously receiving (and dropping) packets.

B. CPU exhaustion attacks

CPU exhaustion attacks aim to consume a victim host’s CPU cycles by continuously sending it requests e.g. ICMP echo request, TCP SYN, SIP INVITE etc. The victim host will continuously process the requests, prepare replies and send them back to fake sender address(es). Depending on its CPU power, the victim’s performance may be degraded to the point that it cannot be used during the attack.

Note that if IPsec is used, packets from untrusted hosts will be quickly dropped without consuming more CPU cycles[6]. However, this assumes that the target host has an IPsec security association with every trusted host in the Internet.

More importantly, an attacker can exploit the Internet Key Exchange (IKEv2) protocol of the IPsec protocol suite[7]. In IKEv2, CPU expensive cryptographic computations are made in response to an IKEv2 initiation request. A well known DoS attack consists of sending an outstanding number of IKEv2 requests and consume the victim’s CPU cycles. IKEv2 supports cookies in order prevent an attacker from spoofing their IP address. In response to an IKEv2 initiation request, the responder returns a cookie in order to check the return routability of the initiator. Only if the initiator used its real IP address it will receive the cookie. A legitimate initiator then repeats its request with the received cookie. The responder, concluding that the initiator is legitimate (i.e. not spoofing IP addresses), proceeds with CPU expensive cryptographic computations that are necessary for key agreement. Consequently, an attacker is forced to use their real network address which can be blocked if frequent requests are made from the same address.

Note however that an attacker can organize a Distributed DoS (DDoS) attack in which thousands of compromised hosts attack using their real address (the attack would probably target many mobile hosts). In this case, cookies would be useless since attacking hosts use their real address and blocking thousands of addresses without denying service to legitimate initiators is a difficult task. A different solution is therefore necessary.

C. Other attacks

Other attacks may also be mounted against future mobile hosts. For example attackers may port scan a target host to find about vulnerabilities, try to obtain unauthorized access or infect the target host with a virus or worm.

D. SPIT: SPam over IP Telephony

Similarly to e-mail, VoIP systems are likely to be abused by malicious parties who initiate unsolicited and unwanted communications. Telemarketers, prank callers, and other telephone system abusers are likely to target VoIP systems. This problem is referred to as SPam over IP Telephony (SPIT)[8].

Unlike battery and CPU exhaustion attacks, this threat is an application-layer threat and disturbs the user in a different way. We show in this paper that the same solution that we develop against battery/CPU exhaustion attacks can be used to fight SPIT.

E. Location privacy attacks

An attacker located anywhere in the Internet can periodically send packets to a victim’s home address without establishing any session, forcing them to send unnecessary binding updates (in route optimization mode) and reveal their location.

IV. DISPOSABLE HOME ADDRESSES

In the proposed model, a mobile host generates a large number of random disposable home addresses pointing to its same home network by sending a home address request
message to its home agent\footnote{In MIPv6 a mobile host has an IPsec security association with its home agent, hence home address generation is secure. When generating home addresses, address collisions can also be detected by the home agent which has a list of all home addresses in the home network.}. Each time Alice is requested her identifier (a home address which is in this case equivalent to a phone number) by another user, she picks a different home address generated by her device and tells it to the peer user if both users are present (referred to as “user contact”) or sends via e-mail if the request was made by e-mail.

When the user moves from one network to another, it configures a new care-of-address as defined in \ref{fig:care-of-address} and sends a binding update for one of its home addresses. In our case, a binding update sent for one home address must update the care-of-address binding for all of the home addresses of the mobile host. I.e., the mobile host can receive an incoming session to any home address that it previously configured and distributed.

Let $hoa_i$ be one of the home addresses of Alice’s battery-powered mobile device. When idle, i.e. not in active communication, Alice’s device is assumed to enter power save mode in which the network interface consumes much less power. As described above an attacker who learned the address $hoa_i$ may attack that address. The attacker may remotely consume the victim’s energy and/or CPU cycles or mount other attacks as described above.

Since Alice has distributed a different home address to each host in her address book, she can block the packets addressed to $hoa_i$. Upon detecting the attack (receipt of an unusually large number of packets to $hoa_i$), Alice’s device needs to send a message to its home agent to indicate that packets destined to $hoa_i$ should be dropped (upon user command). Alice’s device should also configure a new care-of-address (and send to its home agent in a binding update message) if the previous one was sent to the attacker for triangular routing. Clearly, the attacker’s packets will not reach Alice’s device anymore. If in active communication with a legitimate correspondent, that node must also be sent the new care-of-address using a binding update message.

If Alice receives an incoming session from another user, the session will be destined to the home address $hoa_j$, which will be allowed. Blocking one home address does not affect the incoming sessions to other home addresses. Note also that the attacker has no knowledge of the home addresses distributed to other users, thus cannot easily attack another address. When the attack on $hoa_i$ stops, Alice can reactivate that address. Alternatively, the correspondent user that were provided with address $hoa_i$, can request another address by e-mail, instant messaging or using the home address distribution protocol that we describe in Section \ref{sec:distribute-hoas}.

An IPv6 address is 128-bit long: 64 bits network address and 64 bits interface identifier. The total number of home addresses in a home network cannot exceed $2^{64}$. This is not an important problem since $2^{64}$ is a huge number. For example, if 10,000 mobile hosts are served by the same home network and each host has 200 peers in their address book, hence 200 home addresses, then $\frac{2 \times 10^6}{2^{64}} \simeq 2 \times 10^{-12}$ of the available address space in the home network will be in use.

\section{Distributing Disposable Home Addresses}

\subsection{Protocol Description}

As described above, in our proposal, home addresses are used as phone numbers (disposable ones). A disposable home address can be shared when there is user contact by verbal communication, or remotely by e-mail, instant messaging etc. In this section, we develop a protocol for requesting a disposable home address from a target host directly. This protocol will run between peer contact manager applications (see below for benefits).

In this model, each mobile host has a \textit{prime home address}. A disposable home address is first requested from the target’s prime home address and the call is made to the returned disposable home address. Incoming calls to the prime home address are not accepted, and an error message is returned by the target host indicating that a disposable home address must be requested. The prime home address is registered to the DNS and mobile hosts (and hence their users) are identified by the corresponding FQDN (Fully Qualified Domain Name). Users can share their FQDN when there is user contact through verbal communication or remotely by e-mail, instant messaging etc.

Using the proposed protocol, illustrated in Figure\ref{fig:protocol}, Alice’s phone can remotely request a disposable home address from Bob’s phone which is located anywhere in the Internet. The same protocol can be used when there is user contact, i.e. Alice and Bob are both present. Alice enters Bob’s FQDN to her contact manager application which makes a disposable home address request to the target mobile phone’s prime home address. The request contains Alice’s name and possibly other information about Alice, and if possible the request should be signed with Alice’s private key and her certificate must be attached. Upon receipt of the request, the peer application on the target phone displays a message indicating that Alice requests a disposable home address and ask Bob’s permission to return the requested address. If Bob accepts, the address is returned and Alice’s phone can make a call to that address. Bob’s reply containing the disposable home address must be signed using Bob’s private key, and Bob’s certificate must be attached. Note that Alice does not deal with disposable home addresses. She simply makes a call to Bob in her address book and the contact manager requests a disposable home address if necessary and makes the call. The call is made to the disposable home address. If the disposable home address given to Alice is compromised and used for an attack, Bob will block this address as previously described. In this case, Alice’s phone will request a new home address when needed.

This protocol brings the following advantages:

1) Ease of use: Users are less concerned with disposable home addresses since they use FQDNs. They may even ignore that they need one to reach the target host (see below for exceptions). User enters the target FQDN to
the contact manager which requests a disposable home address from the target phone if needed, and makes a call to that address.

2) Speed and reliability: Using the protocol described in this section, a disposable home address can be requested quickly and more reliably. Using e-mail, the requesting user needs to wait until the target user checks e-mail (if push e-mail is not used) and the e-mail servers may be temporarily down, unreachable or congested. Using the proposed protocol, the home address request is directly made to the target host.

3) Publishing a FQDN on the Web: Alice can publish her FQDN on the Web and distribute a different disposable home address to each correspondent that requests a home address. This is advantageous over publishing a disposable home address directly, in which case multiple correspondents would obtain the same disposable home address. If that address is disposed of, all these correspondents would lose contact with Alice.

An attacker who learned Bob’s FQDN and attacking the his prime home address can be defeated by blocking that address address. In this case, the proposed protocol will be temporarily disabled. Correspondents that were previously distributed disposable home addresses can still reach Bob, however. Home address requests can still be made by verbal communication, e-mail, or instant messaging (clearly, in this case, the users should be aware of disposable home addresses). In Section V-C, we discuss this attack’s efficiency in more details.

B. Human interaction proofs

When Alice requests a home address from Bob’s device, a message will be displayed on Bob’s device’s screen, asking permission to return the requested information. This request will interrupt the target user and we see here a potential abuse. 

A malicious user who obtained a target user’s FQDN may repeatedly make fake requests over the Internet in order to disturb the target user, forcing them to repeatedly pushing on NO button and eventually disabling the protocol. This attack would be similar to calling the target user and quickly hanging up. The attacker does not obtain anything, but disturbs the target user. Consequently, in such cases, we would like to ensure that the initiator user makes some relatively harder work compared to the burden put on the target user, i.e. checking the request and making a decision.

In order to prevent spam bots from obtaining a large number of e-mail accounts, HIP (Human Interaction Proof) tests also known as CAPTCHA (Completely Automated Public Turing test to tell Computers and Humans Apart) are used today[9]. As malicious character recognition programs become increasingly intelligent, the HIPS also become more and more difficult to read by humans. There is anecdotal evidence that some users do not comment on blogs when they are required to solve a HIP. Therefore, in our case, HIPS are good candidates to prove hard human work and defeat attackers who try to disturb users with bogus requests displayed on their screen. In the proposed protocol, when frequent home address requests are received by the target device, a HIP is returned to the initiator user, and before a notification is displayed on the target screen, the initiator must first present the correct answer.

The difficulty of the HIP problem can be adaptively increased if the requests are too frequent, which is a sign of anomaly. For example, longer CAPTCHAs can be returned.

C. Simulations

In this section, we present a simulation analysis of the above described home address distribution protocol. In the presented scenario, Alice, upon buying a new mobile phone, publishes her FQDN on the Web and has no contact initially. She has 200 potential correspondent users which find Alice’s FQDN on the Web, make a disposable phone number request from Alice and make a call. Unfortunately, however, an attacker also learns Alice’s FQDN, and hence her prime home address, and mounts battery exhaustion DoS attacks against Alice. The attack consists of continuously flooding the target phone with bogus requests during several hours. We assume that when under attack the prime home address is disabled and consequently correspondents’ disposable home address requests are rejected. Consequently, the attack’s impact is not battery consumption, but rejecting incoming calls from legitimate correspondents. Correspondents who obtain a disposable phone number (when there is no attack) can make further calls even if the prime home address is disabled.

In the first simulation, the attacker mounts a 4-hour attack against Alice’s mobile phone, everyday, where the attack begins at 8:00, 12:00 or 16:00. During a day, the probability of making a call to Alice is $\frac{1}{200}$ for each of 200 correspondent's disposable home addresses and the calls are made between 8:00 and 20:00, i.e., during one of the above three attacks periods. Thus, the probability that a call coincides with an attack is $\frac{1}{4} \times \frac{1}{3} = \frac{1}{12}$. If a disposable phone number was not previously obtained and the call coincides with an attack (i.e., the prime home address is blocked), the call is rejected. In the second simulation, the attacker mounts a 6-hour attack which begins at 8:00 or 14:00. In this case, the probability of rejecting a call is $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$.
The simulation results are shown in Figure 3. In the first simulation, a few calls are rejected, where some calls are still being rejected after 250 days. A total of 18 out of 1,993 calls are rejected (0.9%). In the second simulation, more calls are rejected and even after 500 days a few calls are being rejected. A total of 56 out of 1,993 calls are rejected (2.8%).

We believe however that better results can be expected in practice. In practice, correspondents can also obtain disposable phone numbers through other channels e.g. user contact, e-mail, or instant messaging etc. The only impact of the attack would be therefore forcing a small portion of the correspondents (the rejected ones in Figure 3) to use e-mail, or instant messaging etc. for requesting disposable home addresses. This is not as user friendly as using the described home address distribution protocol but still acceptable. Consequently, we believe that this attack has a low damage/effort ratio and hence is probably unrealistic in practice.

VI. CERTIFICATELESS OPERATION

So far we have assumed that a Public Key Infrastructure (PKI) is available. When Alice makes a disposable home address request to Bob, the request is signed with Alice’s private key, and Bob’s answer is also signed with Bob’s private key and certificates are attached to the messages. Consequently, Bob is certain that the request was made by Alice, and Alice is certain that the returned home address belongs to Bob.

However, if a PKI is not available, the attached certificates will not be verifiable and consequently an attacker can impersonate Alice and/or Bob. For example, by impersonating Alice, an attacker can obtain a home address and attack Bob. Or, by impersonating Bob, and attacker can return her own address and act as a man-in-the-middle.

In this section, we propose a solution to address the case where a PKI is not available.

A. User contact available

When user contact is available, i.e. both users are present, the protocol that is illustrated in Figure 4 can be used for exchanging disposable home addresses and authentic certificates for future use.

Here, we use the theoretical mutual authentication protocol described in [10]. When Alice makes a home address request to Bob (by typing his FQDN), her device first generates a long random string \( Ra \), computes a secure hash \( hash(Ra) \) and sends it along with her public key \( PKa \). Bob’s device generates its own random string \( Rb \) and sends it along with Bob’s public key \( PKb \). Alice’s device responds by sending \( Ra \). Bob’s device computes the secure hash of \( Ra \) and compares it with the previously received \( hash(Ra) \). If they do not match, Bob’s device aborts (not shown). Otherwise it continues. Alice’s device computes and displays a SAS (short authentication string) \( n \)-bit hash, where \( n = 15, 20 \) out of \( Ra, Rb, PKa \) and \( PKb \). Bob’s device computes and displays the same. Alice reads the SAS to Bob through verbal communication (since both users are present, i.e. user contact is available). Alice and Bob compare the received SAS with the one their device computed and displayed. If they do not match, they abort (not shown). Otherwise the devices store each other’s public keys, and securely exchange home addresses.

This protocol is secure against man-in-the-middle attacks. Refer to [10] for a security proof of the protocol.

Since Alice and Bob securely exchanged their public keys, they can update disposable home addresses later when there is no longer user contact. For example, when an attacker learns

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3 We define the damage/effort ratio as the measure of the seriousness of the damages caused by an attack compared to the attacker’s efforts. In this attack, negligible damage is caused by mouths of persistent attack. Hence, it has a low damage/effort ratio.

4 This protocol is actually a solution to the public key distribution problem without PKI. Users, however, are generally not aware of public keys. By integrating this solution into a phone number (disposable home address in our case) exchange protocol, we also contribute to better security in mobile IP telephony. Users are more likely to run a contact management protocol than the pairing protocol described in [10] alone. In this approach, phones get paired when phone numbers are exchanged.
the disposable home address that was given to Alice, Bob can block that address and Alice can request a new one.

B. User contact not available

If user contact is not available, certificateless operation is not secure in the absence of a PKI as described above. In this case, the users can use e-mail or instant messaging to exchange home addresses since these applications are password protected.

VII. FIGHTING SPIT

The proposed model of operation can also be used against SPIT (SPam over IP Telephony). If a user that was given the disposable home address \text{hoa}_i uses it for sending unwanted messages or make disturbing phone calls, the address \text{hoa}_i can be blocked. The malicious user may request another address, however the target user can reject the request.

For example, this model can be used to defeat disturbing calls and messages from a known user e.g. someone met in a party or telemarketing calls from a previously met salesman who was given a disposable home address.

VIII. ARCHITECTURAL CONSIDERATIONS

In the proposed model of operation, a mobile host (and its user) is identified using a FQDN, which can be viewed as a phone number. The FQDN is resolved to the host’s prime home address and disposable home addresses are requested from that address. A host can change its prime home address address at any time and register it to the DNS using dynamic DNS[11]. Disposable home addresses can also be viewed as phone numbers (disposable ones) since a user can use them directly.

It can be noted that SIP URIs in the form of user@provider are not used[4]. End-to-end SIP can be used for session establishment (using IP addresses or FQDNs as SIP URIs), however the proposed model is independent from the SIP architecture, i.e. the SIP proxies are not needed. Mobility is managed by MIPv6. Since it does not rely on SIP infrastructure, the proposed model is more reliable against single points of failure.

Our proposal is however backward compatible, i.e. some users may use the standard model using SIP infrastructure using a fixed single home address at the risk of battery/CPU exhaustion.

One problem with our proposal is offline messaging. In cellular systems, when a target mobile terminal is not online, the caller can leave a message. The message is stored by the network and delivered when the target becomes online again. For this, application-layer solutions are generally necessary, however in our case we do not use application-layer infrastructure. No infrastructure is used other than the Mobile IPv6 home agent and the DNS, and an offline messaging system cannot be possibly integrated into these systems. One solution to this problem is to deploy a peer-to-peer SIP telephony protocol as described in [12]. In this approach, the initiator records a voice message and uploads copies of its message to a number of hosts that are online. Each host can then periodically try to forward the message to the target host until it becomes online. Details, e.g. optimizations, of this solution fall out of this paper’s scope.

IX. LIMITATIONS

In this paper, we are primarily concerned with remote attackers located anywhere in the Internet, attacking a particular known victim’s globally reachable home address. This, we believe, is the most serious case since attacks are possible regardless of the victim’s location.

However, an attacker located in the same cell as the victim, can also learn its MAC address and consume its energy by continuously sending packets to that address. Our solution cannot cope with these attacks. However, upon moving to a new cell, the victim can escape from the attacker.

The care-of-address may reveal the identity of a mobile user if the interface ID part of the address is constructed from the globally unique MAC address. [13] describes privacy extensions for IPv6 where the interface identifier is randomly generated. An attacker may however decide to attack random care-of-addresses in the same subnet. Our solution cannot cope with these attacks. Similarly, the victim can escape from the attacker upon moving to a new subnet or by configuring a new care-of-address.

X. IMPLEMENTATION CONSIDERATIONS

Our problem in this paper is basically a home address management problem. It can be implemented at the application layer. The home address management protocol that we describe will run between the mobile host’s contact manager and a server application run by the home agent. In this approach, the user makes a home address generation request to its contact manager which sends the request to the home agent. The home agent generates an address and configures it for the mobile host. Detecting address collisions is not a problem since the home agent knows all home addresses in its network. The
traffic between mobile host and home agent is protected using IPSec, since they have a security association.

The contact manager application on the mobile host should periodically monitor the mobile host’s traffic, and run intrusion detection algorithms. Upon suspicious activity, it should warn the user and upon user command, block the subject home address by sending a request to the home agent. The home agent should deconfigure the home address. Packets sent to that home address should no longer be served and they should be silently dropped by the home agent. The host should also deconfigure the home address.

Upon blocking the home address, the mobile host needs to configure a new care-of-address and send to its home agent, otherwise the attacker can still reach the mobile host at its care-of-address (if route optimization is used). If bidirectional tunneling method is used, changing the care-of-address is not necessary since the care-of-address is hidden from the attacker.

In this approach, the contact manager applications on different devices also communicate with each other in order to request disposable home addresses using the protocols described in Section V.

XI. RELATED WORK

A. Disposable identifiers

Our proposal was inspired by disposable phone numbers that are in use today[14][15]. Disposable phone numbers are used for coping with unwanted correspondent users. Each user is given a different disposable phone number and if one of the users show malicious behavior (e.g. make unwanted calls) the phone number that was given to that user is canceled.

Disposable e-mail addresses are also in use today, as an alternative way of sharing and managing e-mail addresses[16]. A user distributes a different e-mail address to each correspondent user and if anyone compromises it for any e-mail abuse, the address-owner can easily cancel it without affecting any other contact.

In our case, i.e. in IP telephony, lower level threats also exist, e.g. CPU/energy exhausting DoS attacks as discussed throughout the paper. Consequently, we applied this disposable identifier solution at the IP layer, by proposing disposable IP addresses, i.e. disposable home addresses. This way we can cope with both problems, CPU/energy exhaustion DoS attacks and SPIT, using the same solution.

B. Battery/CPU exhaustion attacks

In [17], the authors warn about so called “sleep deprivation” attacks in the context of mobile ad hoc and sensor networks. This attack consists of periodically sending packets to a victim in order to prevent it from sleep mode.

In [18], the authors offer a thorough analysis of denial-of-service attacks on battery-powered mobile computers. In this paper, three main attack methods are described: (1) service request attacks, where repeated requests are made to the victim for services, typically over a network, (2) benign power attacks where the victim is forced to execute a valid but energy hungry task repeatedly, and (3) malignant power attacks where the attacker modifies or creates an executable to make the system consume more energy than it would otherwise. Our work is different in that we assume that the attacker cannot obtain access to the victim host, and services like ssh are deactivated. In our case, the victim consumes energy for receiving request packets and returning replies. A session is never established. Energy is consumed although the attacker does not obtain access to the target mobile phone.

Key agreement protocols e.g. IKEv2 which employ the Diffie-Hellman protocol, are vulnerable to CPU exhaustion attacks since they rely on CPU expensive operations like exponentiation. An attacker can repeatedly make key agreement requests forcing the victim to continuously make CPU expensive operations. A well-known solution to these attacks is client puzzles[19]. Upon receipt of the initiator’s key agreement request, the responder returns a puzzle. The puzzle is difficult to solve but the proposed result is easy to check. For example, the responder returns a nonce $N$ and the initiator is requested to find a solution $X$ such that the first $k$ bits of $\text{hash}(X, N)$ are zero. The only way to find the solution is brute force, i.e. trying all possible solutions. The solution is easy to check and consists of computing $\text{hash}(X, N)$. Consequently, the attacker makes much more work than the victim, which slows down the attack. This solution can be used to defend against CPU exhaustion attacks, but energy is still consumed for receiving packets (deprived from power save mode) and responding with puzzle requests. In addition, an attacker may orchestrate a DoS attack using tens of thousands of compromised hosts and consequently use much higher CPU power than the victim(s). I.e., each host participating in the attack may need longtime to solve the requested puzzles, but the overall attack performance may be good enough to exhaust the CPU/battery of victim(s). A different solution e.g. disposable home addresses is therefore necessary.

C. SPIT

[20] provides a detailed analysis of the SPIT threat in the context of SIP. The authors identify three threats: Call spam, instant messaging spam and presence spam. They also analyze the solution space and propose various solutions e.g. content filtering, black lists, white lists, reputation systems, limited use addresses etc. Among these solutions limited use addresses are very similar to our proposal. The authors do not propose a solution for SIP, but instead they bring to our attention the use of limited use addresses for protection against e-mail spam, where each correspondent user is given a different e-mail address.

Our proposal is different in that we use disposable IP addresses in order to overcome not only the SPIT problem but also the battery/CPU exhaustion threats. We agree however...
that more than one solutions can be applied to the SPIT problem.

D. Pseudo home addresses

In [21] the authors describe the use of a pseudo home address to achieve location privacy. A pseudo home address is used to replace the real home address in various messages, which allows the mobile node to hide its real home address from both the correspondent node and eavesdroppers.

E. Network ingress filtering

An alternative solution against Internet attacks is network ingress filtering, which consists of dropping packets which have topologically incorrect source address [22]. We believe that this is a good solution in theory, however note that most service providers to not employ ingress filtering. This solution is also not effective against DDoS attacks in which the attacker controls a large number attacking hosts which send packets with their real IP address.

XII. Conclusion

In this paper we proposed disposable home addresses for Mobile IPv6 (MIPv6). In summary, the proposed solution will help defend against the following security problems in future mobile IP telephony:

- Battery exhaustion Denial-of-Service (DoS) attacks that deprive a target host from sleep mode (important since mobile hosts are battery powered and energy is a scarce resource)
- Battery exhaustion DoS attacks that force a target host to return reply packets and link-layer ACKs
- CPU exhaustion DoS attacks that force a target to process incoming malicious packets and return replies
- CPU exhaustion DoS attacks that force the target to perform CPU-expensive cryptographic operations in IKEv2 (unlike client puzzles, defense is possible against DDoS attacks)
- Disturbing calls and messages from a known user e.g. someone met in party or telemarketing calls from a previously met salesman (subset of the SPam over IP telephony problem)
- Other attacks e.g. port scanning, or currently unknown attacks may also be defeated

These defenses are achieved by distributing a different "disposable" home address to each correspondent. When one of the addresses is exploited for an attack, it is disposed of by its owner i.e. the mobile user. Other correspondents that were distributed different home addresses can still reach the user. It is also possible to request a new disposable home address when one of them is disabled.

It is noteworthy that the proposed model of operation is only possible in IPv6 since a large number of mobile hosts may be served by the home network and each mobile host may have hundreds of disposable home addresses. In IPv6, 2^64 addresses are supported in a same subnet, which is much more than enough.

The proposed model is especially useful against battery exhausting DoS attacks and CPU exhausting distributed DoS attacks, since it seems to be the only viable solution, currently. We believe that these attacks are fundamentally difficult to defeat and represent a considerable threat against comfortable use of future wireless Internet. Without the solution proposed in this paper, the only defense seems to be turning off the phone that is under attack, for later use when the attack ceases.

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