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Internet Printing Protocol (IPP) over HTTPS Transport Binding
and the 'ipps' URI Scheme

Abstract

This document defines the Internet Printing Protocol (IPP) over HTTPS transport binding and the corresponding 'ipps' URI scheme, which is used to designate the access to the network location of a secure IPP print service or a network resource managed by such a service.

This document defines an alternate IPP transport binding to that defined in the original IPP URL Scheme (RFC 3510), but this document does not update or obsolete RFC 3510.

This document updates RFCs 2910 and 2911.

Status of This Memo

This is an Internet Standards Track document.

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1. Introduction

This document defines the Internet Printing Protocol (IPP) over HTTPS transport binding and the corresponding 'ipps' URI scheme, which is used to designate the access to the network location of a secure IPP print service or a network resource managed by such a service.

This document has been submitted to the IETF by the Internet Printing Protocol Working Group (WG) of the IEEE-ISTO Printer Working Group, as part of their PWG "IPP Everywhere" (PWG 5100.14) project for secure mobile printing with vendor-neutral Client software.

This document defines an alternate IPP transport binding to that defined in the original IPP URL Scheme [RFC3510], but this document does not update or obsolete [RFC3510].

This document updates:

- a) "Internet Printing Protocol/1.1: Encoding and Transport" [RFC2910], by extending Section 4 ("Encoding of Transport Layer"), Section 5 ("IPP URL Scheme"); and Section 8.2 ("Using IPP with TLS") to add the new standard URI scheme of 'ipps' for IPP Printers; and
- b) "Internet Printing Protocol/1.1: Model and Semantics" [RFC2911], by extending Section 4.1.6 ("uriScheme") and Section 4.4.1 ("printer-uri-supported") to add the new standard URI scheme of 'ipps' for IPP Printers.

The following versions of IPP are currently defined:

- a) 1.0 in [RFC2566] (obsolete);
- b) 1.1 in [RFC2911];
- c) 2.0 in [PWG5100.12];
- d) 2.1 in [PWG5100.12]; and
- e) 2.2 in [PWG5100.12].

Overview information about IPP is available in Section 1 of [RFC2911], Section 1 of [RFC3196], and Section 1 of PWG "IPP Version 2.0 Second Edition (IPP/2.0 SE)" [PWG5100.12].

1.1. Structure of This Document

This document contains the following sections:

Section 2 defines the conventions and terms used throughout the document.

Section 3 defines the IPP over HTTPS transport binding.

Section 4 defines the 'ipps' URI scheme.

Sections 5 and 6 contain IANA and security considerations, respectively.

Section 7 contains references.

1.2. Rationale for This Document

The 'ipps' URI scheme was defined for the following reasons:

- 1) Some existing IPP Client and IPP Printer implementations of "Upgrading to TLS Within HTTP/1.1" [RFC2817] are flawed and unreliable, although this is not due to specification defects in [RFC2817] itself.
- 2) Some existing IPP Client and IPP Printer implementations of HTTP upgrade [RFC2817] do not perform an upgrade at the beginning of every HTTP [RFC7230] connection; instead, they only shift to secure IPP for selected IPP operations (inherently dangerous behavior on the same underlying TCP [RFC793] connection).
- 3) IPP Printer server-mandated HTTP upgrade [RFC2817] can still lead to exposure of IPP Client data if the Expect request header is not used -- basically, the IPP Client can send its whole Print-Job request before the IPP Printer has a chance to respond and say, "Wait! You need to encrypt first!".

2. Conventions Used in This Document

2.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

2.2. Printing Terminology

The reader of this document needs to be familiar with the printing terms defined in "Internet Printing Protocol/1.1: Model and Semantics" [RFC2911] as well as the following:

IPP Client: The software (on some hardware platform) that submits IPP Job creation and IPP Printer and IPP Job management operations via the IPP over HTTP transport binding defined in the IPP/1.1 Encoding and Transport document [RFC2910] and/or the IPP over HTTPS transport binding defined in Section 3 of this specification to an IPP Printer (print spooler, print gateway, or physical printing device).

IPP Job: The set of attributes and documents for one print job instantiated in an IPP Printer.

IPP Job object: Synonym for IPP Job.

IPP Printer: The software (on some hardware platform) that receives IPP Job creation and IPP Printer and IPP Job management operations via the IPP over HTTP transport binding defined in the IPP/1.1 Encoding and Transport document [RFC2910] and/or the IPP over HTTPS transport binding defined in Section 3 of this specification from an IPP Client.

IPP Printer object: Synonym for IPP Printer.

'ipps' URI: A URI using the 'ipps' URI scheme defined in Section 4 of this specification.

2.3. Abbreviations

This document makes use of the following abbreviations (given with their expanded forms and references for further reading):

ABNF	- Augmented Backus-Naur Form [STD68]
ASCII	- American Standard Code for Information Interchange [ASCII]
HTTP	- HyperText Transfer Protocol [RFC7230]
HTTPS	- HTTP over TLS [RFC7230]
IANA	- Internet Assigned Numbers Authority < http://www.iana.org >
IEEE	- Institute of Electrical and Electronics Engineers < http://www.ieee.org >
IESG	- Internet Engineering Steering Group < http://www.ietf.org/iesg/ >
IPP	- Internet Printing Protocol [RFC2911] and [PWG5100.12] < http://www.pwg.org/ipp/ >
ISTO	- IEEE Industry Standards and Technology Organization < http://www.ieee-isto.org/ >
LPD	- Line Printer Daemon Protocol [RFC1179]
PWG	- IEEE-ISTO Printer Working Group < http://www.pwg.org >
RFC	- Request for Comments < http://www.rfc-editor.org >

TCP - Transmission Control Protocol [RFC793]
TLS - Transport Layer Security [RFC5246]
URI - Uniform Resource Identifier [STD66]
URL - Uniform Resource Locator [STD66]
UTF-8 - Unicode Transformation Format - 8-bit [STD63]

3. IPP over HTTPS Transport Binding

This document defines the following alternate IPP over HTTPS transport binding for the abstract protocol defined in "Internet Printing Protocol/1.1: Model and Semantics" [RFC2911] and IEEE-ISTO PWG "IPP Version 2.0 Second Edition (IPP/2.0 SE)" [PWG5100.12].

When using an 'ipps' URI, an IPP Client MUST establish an IPP application-layer connection according to the following sequence:

- 1) The IPP Client selects an 'ipps' URI value from a "printer-uri-supported" Printer attribute [RFC2911], a directory entry, discovery info, a web page, etc.;
- 2) The IPP Client converts the 'ipps' URI to an 'https' URI [RFC7230] (replacing 'ipps' with 'https' and inserting the port number from the URI or port 631 if the URI doesn't include an explicit port number);
- 3) The IPP Client establishes an HTTPS [RFC7230] secure session layer connection to the target endpoint; and
- 4) The IPP Client sends requests to and receives responses from the target IPP application-layer resource over the HTTPS [RFC7230] secure session layer connection using the POST method defined in [RFC7231].

4. Definition of 'ipps' URI Scheme

4.1. Applicability of 'ipps' URI Scheme

Per PWG "IPP Everywhere" [PWG5100.14], in IPP exchanges, the 'ipps' URI scheme MUST only be used:

- a) To specify an absolute URI for IPP secure print services and their associated network resources;
- b) To specify the use of the abstract protocol defined in "Internet Printing Protocol/1.1: Model and Semantics" [RFC2911] and IEEE-ISTO PWG "IPP Version 2.0 Second Edition (IPP/2.0 SE)" [PWG5100.12]; and
- c) To specify the use of the transport binding defined in this document.

The 'ipps' URI scheme allows an IPP Client to choose an appropriate IPP secure print service (for example, from a directory). The IPP Client can establish an HTTPS connection to the specified IPP secure print service. The IPP Client can send IPP requests (for example, Print-Job requests) and receive IPP responses over that HTTPS connection.

See: Section 4.2 ("Syntax of 'ipps' URI Scheme") of this document.

See: Section 4.4.1 ("printer-uri-supported") in [RFC2911].

See: Section 5 ("IPP URL Scheme") in [RFC2910].

See: Section 4 ("IPP Standards") of IEEE-ISTO PWG "IPP Version 2.0 Second Edition (IPP/2.0 SE)" [PWG5100.12].

4.2. Syntax of 'ipps' URI Scheme

The abstract protocol defined in [RFC2911] places a limit of 1023 octets (NOT characters) on the length of a URI.

See: "Uniform Resource Identifier (URI): Generic Syntax" [STD66].

Per PWG "IPP Everywhere" [PWG5100.14], for compatibility with existing IPP implementations, IPP Printers SHOULD NOT generate 'ipp' [RFC3510] or 'ipps' URI (or allow administrators to configure) lengths above 255 octets, because many older IPP Client implementations do not properly support these lengths.

Per PWG "IPP Everywhere" [PWG5100.14], in IPP exchanges, 'ipps' URIs MUST be represented in absolute form. Absolute URIs always begin with a scheme name followed by a colon. For definitive information on URI syntax and semantics, see "Uniform Resource Identifier (URI): Generic Syntax and Semantics" [STD66]. This specification adopts the definitions of "host", "port", and "query" from [STD66]. This specification adopts the definition of "absolute-path" from [RFC7230].

The 'ipps' URI scheme syntax in ABNF [STD68] is defined as follows:

```
ipps-uri =  
  "ipps:" "/" host [ ":" port ] [ absolute-path [ "?" query ]]
```

Per [RFC2910], if the port is empty or not given, then port 631 MUST be used.

See: Section 4.3 ("Associated Port for 'ipps' URI Scheme") in this document.

The semantics are that the identified resource (see [RFC7230]) is located at the IPP secure print service listening for HTTPS connections on that port of that host; and the Request-URI for the identified resource is 'absolute-path'.

Note: The higher-level "authority" production is not imported from [STD66], because it includes an optional "userinfo" component that cannot be used in 'ipps' URIs.

Note: The "query" production does not have defined semantics in IPP and was never used in examples in the IPP/1.1 Encoding and Transport document [RFC2910] or the original IPP URL Scheme [RFC3510]. The "query" is retained here for consistency, but IPP Clients SHOULD avoid its use (because the semantics would be implementation defined).

Note: Per PWG "IPP Everywhere" [PWG5100.14], literal IPv4 or IPv6 addresses SHOULD NOT be used in 'ipps' URIs, because:

- a) IP addresses are often changed after network device installation (for example, based on DHCP reassignment after a power cycle);
- b) IP addresses often don't map simply to security domains;
- c) IP addresses are difficult to validate with X.509 server certificates (because they do not map to common name or alternate name attributes); and

d) IP link local addresses are not "portable" due to link identity.

Per [RFC2910], if the 'absolute-path' is not present in an IPP URI, it MUST be given as "/" when used as a Request-URI for a resource (see [RFC7230]). An 'ipps' URI is transformed into an 'https' URI by replacing "ipps:" with "https:" and inserting port 631 (if an explicit 'port' is not present in the original 'ipps' URI).

See: Section 4.3 ("Associated Port for 'ipps' URI Scheme") in this document.

4.3. Associated Port for 'ipps' URI Scheme

Per [RFC2910], all 'ipps' URIs that do NOT explicitly specify a port MUST be resolved to IANA-assigned well-known port 631, already registered in [PORTREG] by [RFC2910].

Note: Per direction of the IESG, as described in [RFC2910], port 631 is used for all IPP connections (with or without TLS [RFC5246]). Therefore, port 631 is used for both 'ipp' [RFC3510] and 'ipps' URIs, which both refer to an IPP Printer or a network resource managed by an IPP Printer. IPP Printer implementors can refer to the CUPS [CUPS] source code for an example of incoming connection handling for the dual use of port 631.

See: IANA Port Numbers Registry [PORTREG].

See: [RFC2910].

4.4. Character Encoding of 'ipps' URI Scheme

Per PWG "IPP Everywhere" [PWG5100.14], 'ipps' URIs MUST:

- a) Use the UTF-8 [STD63] charset for all components; and
- b) Use [STD66] rules for percent encoding data octets outside the US-ASCII-coded character set [ASCII].

4.5. Examples of 'ipps' URIs

The following are examples of well-formed 'ipps' URIs for IPP Printers (for example, to be used as protocol elements in 'printer-uri' operation attributes of Print-Job request messages):

```
ipps://example.com/  
ipps://example.com/ipp  
ipps://example.com/ipp/faxout  
ipps://example.com/ipp/print  
ipps://example.com/ipp/scan  
ipps://example.com/ipp/print/bob  
ipps://example.com/ipp/print/ira
```

Note: The use of an explicit 'ipp' path component followed by explicit 'print', 'faxout', 'scan', or other standard or vendor service component is best practice per [PWG5100.14], [PWG5100.15], and [PWG5100.17].

Each of the above URIs is a well-formed URI for an IPP Printer and each would reference a logically different IPP Printer, even though some of those IPP Printers might share the same host system. Note that 'print' might represent some grouping of IPP Printers (for example, a load-balancing spooler), while the 'bob' or 'ira' last path components might represent two different physical printer devices, or 'bob' and 'ira' might represent separate human recipients on the same physical printer device (for example, a physical printer supporting two job queues). Regardless, both 'bob' and 'ira' would behave as different and independent IPP Printers.

The following are examples of well-formed 'ipps' URIs for IPP Printers with (optional) ports and paths:

```
ipps://example.com/  
ipps://example.com/ipp/print  
ipps://example.com:631/ipp/print
```

The first and second 'ipps' URIs above will be resolved to port 631 (IANA-assigned well-known port for IPP). The second and third 'ipps' URIs above are equivalent (see Section 4.6).

See: Sections 4.2 ("Syntax of 'ipps' URI Scheme") and 4.3 ("Associated Port for 'ipps' URI Scheme") in this document.

4.6. Comparisons of 'ipps' URIs

Per PWG "IPP Everywhere" [PWG5100.14], when comparing two 'ipps' URIs to decide whether or not they match, an IPP Client MUST use the same rules as those defined for 'http' and 'https' URI comparisons in [RFC7230], with the following single exception:

- A port that is empty or not given MUST be treated as equivalent to the well-known port for that 'ipps' URI (port 631).

See: Section 4.3 ("Associated Port for 'ipps' URI Scheme") in this document.

See: Section 2.7.3 ("http and https URI Normalization and Comparison") in [RFC7230].

5. IANA Considerations

IANA has registered the new keyword value 'ipps' for the IPP Printer "printer-uri-supported" attribute in the IANA IPP Registry [IPPREG], per Section 6.2 ("Attribute Extensibility") of [RFC2911] as follows:

IANA has registered the 'ipps' URI scheme using the following template, which conforms to [BCP35].

URI scheme name: ipps

Status: Permanent

URI scheme syntax: See Section 4.2 of RFC 7472.

URI scheme semantics: The 'ipps' URI scheme is used to designate secure IPP Printer objects (print spoolers, print gateways, print devices, etc.) on Internet hosts accessible using the IPP enhanced to support guaranteed data integrity and negotiable data privacy using TLS [RFC5246] as specified in HTTP/1.1 [RFC7230].

Encoding Considerations: See Section 4.4 of RFC 7472.

Applications/protocols that use this URI scheme name: The 'ipps' URI scheme is intended to be used by applications that need to access secure IPP Printers using the IPP enhanced to support guaranteed data integrity and negotiable data privacy using TLS [RFC5246] as specified in HTTP/1.1 [RFC7230]. Such applications may include (but are not limited to) IPP-capable web browsers, IPP Clients that wish to print a file, and servers (for example, print spoolers) wishing to forward a Job for processing.

Interoperability Considerations: The widely deployed, open source IPP print service CUPS [CUPS] (on most UNIX, Linux, and Apple OS X systems) has supported 'ipps' URI for several years before the publication of this document. PWG "IPP Everywhere" [PWG5100.14] (IPP secure, mobile printing extensions) requires the use of 'ipps' URI for mandatory data integrity and negotiable data confidentiality.

Security Considerations: See Section 6 of RFC 7472.

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References: RFCs 2910, 2911, and 7472; IEEE-ISTO PWG 5100.12.

6. Security Considerations

6.1. Problem Statement

Powerful mobile devices (laptops, tablets, smartphones, etc.) are now commonly used to access enterprise and Cloud print services across the public Internet. This is the primary use case for PWG "IPP Everywhere" [PWG5100.14], which has already been adopted by operating system and printer vendors and several other public standards bodies. End-user and enterprise documents and user privacy-sensitive information are at greater risk than ever before. This IPP-over-HTTPS transport binding and 'ipps' URI scheme specification was defined to enable high availability combined with secure operation in this dynamic environment (for example, wireless hotspots in hotels, airports, and restaurants).

See: Section 1 ("Introduction") of [PWG5100.14].

See: Section 3.1 ("Rationale") of [PWG5100.14].

6.1.1. Targets of Attacks

A network print spooler (logical printer) or print device (physical printer) is potentially subject to attacks, which may target:

- a) The network (to compromise the routing infrastructure, for example, by creating congestion);
- b) The Internet Printing Protocol (IPP) [RFC2911] (for example, to compromise the normal behavior of IPP);
- c) The print job metadata (for example, to extract privacy-sensitive information from the job submission request or via query of the job on the IPP Printer); or
- d) The print document content itself (for example, to steal the data or to corrupt the documents being transferred).

6.1.2. Layers of Attacks

Attacks against print services can be launched:

- a) Against the network infrastructure (for example, TCP [RFC793] congestion control);
- b) Against the IPP data flow itself (for example, by sending forged packets or forcing TLS [RFC5246] version downgrade); or
- c) Against the IPP operation parameters (for example, by corrupting requested document processing attributes).

6.2. Attacks and Defenses

This 'ipps' URI Scheme specification adds the following additional security considerations to those described in [RFC7230], [RFC2910], [RFC2911], [RFC5246], [RFC7230], [PWG5100.12], and [STD66].

See: Section 8 ("Security Considerations") in [RFC2910].

See: Section 8 ("Security Considerations") in [RFC2911].

See: Appendix D ("Implementation Notes"), Appendix E ("Backward Compatibility"), and Appendix F ("Security Analysis") of [RFC5246].

See: Section 10 ("Security Considerations") in [PWG5100.12].

See: Section 7 ("Security Considerations") in [STD66].

6.2.1. Faked 'ipps' URI

An 'ipps' URI might be faked to point to a rogue IPP secure print service, thus collecting confidential job metadata or document contents from IPP Clients.

Due to administrator reconfiguration or physical relocation of an IPP Printer, a former literal IPv4 or IPv6 address might no longer be valid. See Section 4.2 ("Syntax of 'ipps' URI Scheme") for the recommendation against the use of literal IP addresses in 'ipps' URI.

Server authentication mechanisms and security mechanisms specified in IPP/1.1 Encoding and Transport [RFC2910], HTTP/1.1 [RFC7230], and TLS/1.2 [RFC5246] can be used to address this threat.

6.2.2. Unauthorized Access by IPP Client

An 'ipps' URI might be used to access an IPP secure print service by an unauthorized IPP Client, for example, extracting privacy-sensitive information such as "job-originating-user-name" job metadata defined in [RFC2911].

Client authentication mechanisms and security mechanisms specified in IPP/1.1 Encoding and Transport [RFC2910], HTTP/1.1 [RFC7230], and TLS/1.2 [RFC5246] can be used to address this threat.

6.2.3. Compromise at Application Layer Gateway

An 'ipps' URI might be used to access an IPP secure print service at a print protocol application layer gateway (for example, an IPP to LPD [RFC1179] gateway [RFC2569]), potentially causing silent compromise of IPP security mechanisms.

There is no general defense against this threat by an IPP Client. System administrators SHOULD avoid such configurations.

6.2.4. No Client Authentication for 'ipps' URI

An 'ipps' URI does not define parameters to specify the required IPP Client authentication mechanism (for example, 'certificate' as defined in Section 4.4.2 ("uri-authentication-supported") of [RFC2911]).

An IPP Client SHOULD first use service discovery or directory protocols (e.g., the "Lightweight Directory Access Protocol (LDAP): Schema for Printer Services" [RFC3712]) or directly send an IPP Get-Printer-Attributes operation to the target IPP Printer to read

"printer-uri-supported", "uri-authentication-supported", and "uri-security-supported" attributes to discover the required IPP Client authentication and security mechanisms for each supported URI.

6.3. TLS Version Requirements

Per PWG "IPP Everywhere" [PWG5100.14] (and in accordance with security best practices and all existing deployments of the 'ipps' URI scheme), IPP Clients and IPP Printers that support this specification MUST use TLS/1.2 [RFC5246] or a higher version, for all 'ipps' secure transport layer connections.

Implementors will find useful advice in the "Recommendations for Secure Use of TLS and DTLS" [TLSBCP].

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This document defines an alternate IPP transport binding to that defined in the original IPP URL Scheme [RFC3510], but this document does not update or obsolete [RFC3510].

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