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Internationalized Domain Names for Applications (IDNA): Background,  
Explanation, and Rationale  
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## Abstract

Several years have passed since the original protocol for Internationalized Domain Names (IDNs) was completed and deployed. During that time, a number of issues have arisen, including the need to update the system to deal with newer versions of Unicode. Some of these issues require tuning of the existing protocols and the tables on which they depend. This document provides an overview of a revised system and provides explanatory material for its components.

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## [1.](#) Introduction

### [1.1.](#) Context and Overview

The original standards for Internationalized Domain Names (IDNs) were completed and deployed starting in 2003. Those standards are known as Internationalized Domain Names in Applications (IDNA), taken from the name of the highest level standard within the group, [RFC 3490](#) [[RFC3490](#)]. After those standards were deployed, a number of issues arose that led to a call for a new version of the IDNA protocol and the associated tables, including a subset of those described in a recent IAB report [[RFC4690](#)] and the need to update the system to deal with newer versions of Unicode. This document further explains the issues that have been encountered when they are important to understanding of the revised protocols. It also provides an overview of the new IDNA model and explanatory material for it. Additional explanatory material for the specific components of the proposals appears with the associated documents.

This document and the associated ones are written from the perspective of an IDNA-aware user, application, or implementation. While they may reiterate fundamental DNS rules and requirements for the convenience of the reader, they make no attempt to be comprehensive about DNS principles and should not be considered as a substitute for a thorough understanding of the DNS protocols and specifications.

A good deal of the background material that appeared in [RFC 3490](#) [[RFC3490](#)] has been removed from this update. That material is either

of historical interest only or has been covered from a more recent perspective in [RFC 4690](#) [[RFC4690](#)].

This document is not normative. The information it provides is intended to make the rules, tables, and protocol easier to understand and to provide overview information and suggestions for zone administrators and others who need to make policy, deployment, and similar decisions about IDNs.

## [1.2.](#) Discussion Forum

[[ RFC Editor: please remove this section. ]]

IDNA2008 is being discussed in the IETF "idnabis" Working Group and on the mailing list [idna-update@alvestrand.no](mailto:idna-update@alvestrand.no)

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## [1.3.](#) Terminology

Terminology that is critical for understanding this document and the rest of the documents that make up IDNA2008, appears in [[IDNA2008-Defs](#)]. That document also contains roadmap to the IDNA2008 document collection. No attempt should be made to understand this document without the definitions and concepts that appear there.

### [1.3.1.](#) Documents and Standards

This document uses the term "IDNA2003" to refer to the set of standards that make up and support the version of IDNA published in 2003, i.e., those commonly known as the IDNA base specification [[RFC3490](#)], Nameprep [[RFC3491](#)], Punycode [[RFC3492](#)], and Stringprep [[RFC3454](#)]. In this document, those names are used to refer, conceptually, to the individual documents, with the base IDNA specification called just "IDNA".

The term "IDNA2008" is used to refer to a new version of IDNA as described in this document and in the documents described in the document listing of [[IDNA2008-Defs](#)]. IDNA2008 is not dependent on any of the IDNA2003 specifications other than the one for Punycode

encoding. References to "these specifications" or "these documents" are to the entire IDNA2008 set.

### [1.3.2.](#) DNS "Name" Terminology

These documents depart from historical DNS terminology and usage in one important respect. Over the years, the community has talked very casually about "names" in the DNS, beginning with calling it "the domain name system". That terminology is fine in the very precise sense that the identifiers of the DNS do provide names for objects and addresses. But, in the context of IDNs, the term has introduced some confusion, confusion that has increased further as people have begun to speak of DNS labels in terms of the words or phrases of various natural languages.

Historically, many, perhaps most, of the "names" in the DNS have been mnemonics to identify some particular concept, object, or organization. They are typically derived from, or rooted in, some language because most people think in language-based ways. But, because they are mnemonics, they need not obey the orthographic conventions of any language: it is not a requirement that it be possible for them to be "words".

This distinction is important because the reasonable goal of an IDN effort is not to be able to write the great Klingon (or language of one's choice) novel in DNS labels but to be able to form a usefully

broad range of mnemonics in ways that are as natural as possible in a very broad range of scripts.

### [1.3.3.](#) New Terminology and Restrictions

These documents introduce new terminology, and precise definitions, for the terms "U-label", "A-Label", LDH-label (to which all valid pre-IDNA host names conformed), Reserved-LDH-label (R-LDH-label), XN-label, Fake-A-Label, and Non-Reserved-LDH-label (NR-LDH-label).

In addition, the term "putative label" has been adopted to refer to a label that may appear to meet certain definitional constraints but has not yet been sufficiently tested for validity.

These definitions are illustrated in Figure 1 of the Definitions

Document [[IDNA2008-Defs](#)]. R-LDH-labels contain "--" in the third and fourth character from the beginning of the label. In IDNA-aware applications, only a subset of these reserved labels is permitted to be used, namely the A-label subset. A-labels are a subset of the R-LDH-labels that begin with the case-insensitive (?) string "xn--". Labels that bear this prefix but which are not otherwise valid fall into the "Fake-A-label" category. The non-reserved labels (NR-LDH-labels) are implicitly valid since they do not trigger any resemblance to IDNA-landr NR-LDH-labels.

The creation of the Reserved-LDH category is required for three reasons:

- o to prevent confusion with pre-IDNA coding forms;
- o to permit future extensions that would require changing the prefix, no matter how unlikely those might be (see [Section 7.4](#)); and
- o to reduce the opportunities for attacks via the Punycode encoding algorithm itself.

#### [1.4.](#) Objectives

The intent of the IDNA revision effort, and hence of this document and the associated ones, is to increase the usability and effectiveness of internationalized domain names (IDNs) while preserving or strengthening the integrity of references that use them. The original "hostname" character definitions (see, e.g., [[RFC0810](#)]) struck a balance between the creation of useful mnemonics and the introduction of parsing problems or general confusion in the contexts in which domain names are used. The objective of IDNA2008 is to preserve that balance while expanding the character repertoire

to include extended versions of Roman-derived scripts and scripts that are not Roman in origin. No work of this sort is able to completely eliminate sources of visual or textual confusion: such confusion is possible even under the original host naming rules where only ASCII characters were permitted. However, through the application of different techniques at different points (see [Section 3.3](#)), it should be possible to keep problems to an acceptable minimum. One consequence of this general objective is that the

desire of some user or marketing community to use a particular string --whether the reason is to try to write sentences of particular languages in the DNS, to express a facsimile of the symbol for a brand, or for some other purpose-- is not a primary goal within the context of applications in the domain name space.

#### [1.5.](#) Applicability and Function of IDNA

The IDNA specification solves the problem of extending the repertoire of characters that can be used in domain names to include a large subset of the Unicode repertoire.

IDNA does not extend the service offered by DNS to the applications. Instead, the applications (and, by implication, the users) continue to see an exact-match lookup service. Either there is a single exactly-matching name or there is no match. This model has served the existing applications well, but it requires, with or without internationalized domain names, that users know the exact spelling of the domain names that are to be typed into applications such as web browsers and mail user agents. The introduction of the larger repertoire of characters potentially makes the set of misspellings larger, especially given that in some cases the same appearance, for example on a business card, might visually match several Unicode code points or several sequences of code points.

The IDNA standard does not require any applications to conform to it, nor does it retroactively change those applications. An application can elect to use IDNA in order to support IDN while maintaining interoperability with existing infrastructure. If an application wants to use non-ASCII characters in domain names, IDNA is the only currently-defined option. Adding IDNA support to an existing application entails changes to the application only, and leaves room for flexibility in front-end processing and more specifically in the user interface (see [Section 6](#)).

A great deal of the discussion of IDN solutions has focused on transition issues and how IDNs will work in a world where not all of the components have been updated. Proposals that were not chosen by the original IDN Working Group would have depended on updating of user applications, DNS resolvers, and DNS servers in order for a user

to apply an internationalized domain name in any form or coding



acceptable under that method. While processing must be performed prior to or after access to the DNS, IDNA requires no changes to the DNS protocol or any DNS servers or the resolvers on user's computers.

IDNA allows the graceful introduction of IDNs not only by avoiding upgrades to existing infrastructure (such as DNS servers and mail transport agents), but also by allowing some rudimentary use of IDNs in applications by using the ASCII-encoded representation of the labels containing non-ASCII characters. While such names are user-unfriendly to read and type, and hence not optimal for user input, they can be used as a last resort to allow rudimentary IDN usage. For example, they might be the best choice for display if it were known that relevant fonts were not available on the user's computer. In order to allow user-friendly input and output of the IDNs and acceptance of some characters as equivalent to those to be processed according to the protocol, the applications need to be modified to conform to this specification.

This version of IDNA uses the Unicode character repertoire, for continuity with the original version of IDNA.

#### 1.6. Comprehensibility of IDNA Mechanisms and Processing

One of the major goals of this work is to improve the general understanding of how IDNA works and what characters are permitted and what happens to them. Comprehensibility and predictability to users and registrants are themselves important motivations and design goals for this effort. The effort includes some new terminology and a revised and extended model, both covered in this section, and some more specific protocol, processing, and table modifications. Details of the latter appear in other documents (see [[IDNA2008-Defs](#)]).

Several issues are inherent in the application of IDNs and, indeed, almost any other system that tries to handle international characters and concepts. They range from the apparently trivial --e.g., one cannot display a character for which one does not have a font available locally-- to the more complex and subtle. Many people have observed that internationalization is just a tool to enable effective localization while permitting some global uniformity. Issues of display, of exactly how various strings and characters are entered, and so on are inherently issues about localization and user interface design.

A protocol such as IDNA can only assume that such operations as data entry and reconciliation of differences in character forms are possible. It may make some recommendations about how display might work when characters and fonts are not available, but they can only

be general recommendations and, because display functions are rarely controlled by the types of applications that would call upon IDNA, will rarely be very effective.

However, shifting responsibility for character mapping and other adjustments from the protocol (where it was located in IDNA2003) to the user interface or processing before invoking IDNA raises issues about both what that processing should do and about compatibility for references prepared in an IDNA2003 context. Those issues are discussed in [Section 6](#).

Operations for converting between local character sets and normalized Unicode are part of this general set of user interface issues. The conversion is obviously not required at all in a Unicode-native system that maintains all strings in Normalization Form C (NFC). (See [[Unicode-UAX15](#)] for precise definitions of NFC and NFKC if needed.) It may, however, involve some complexity in a system that is not Unicode-native, especially if the elements of the local character set do not map exactly and unambiguously into Unicode characters or do so in a way that is not completely stable over time. Perhaps more important, if a label being converted to a local character set contains Unicode characters that have no correspondence in that character set, the application may have to apply special, locally-appropriate, methods to avoid or reduce loss of information.

Depending on the system involved, the major difficulty may not lie in the mapping but in accurately identifying the incoming character set and then applying the correct conversion routine. If a local operating system uses one of the ISO 8859 character sets or an extensive national or industrial system such as GB18030 [[GB18030](#)] or BIG5 [[BIG5](#)], one must correctly identify the character set in use before converting to Unicode even though those character coding systems are substantially or completely Unicode-compatible (i.e., all of the code points in them have an exact and unique mapping to Unicode code points). It may be even more difficult when the character coding system in local use is based on conceptually different assumptions than those used by Unicode about, e.g., font encodings used for publications in some Indic scripts. Those differences may not easily yield unambiguous conversions or interpretations even if each coding system is internally consistent and adequate to represent the local language and script.

## [2](#). Processing in IDNA2008

These specifications separate Domain Name Registration and Lookup in

the protocol specification. Doing so reflects current practice in which per-registry restrictions and special processing are applied at

registration time but not during lookup. Even more important in the longer term, it facilitates incremental addition of permitted character groups to avoid freezing on one particular version of Unicode.

The actual registration and lookup protocols for IDNA2008 are specified in [[IDNA2008-Protocol](#)].

### [3.](#) Permitted Characters: An Inclusion List

This section provides an overview of the model used to establish the algorithm and character lists of [[IDNA2008-Tables](#)] and describes the names and applicability of the categories used there. Note that the inclusion of a character in the first category group ([Section 3.1.1](#)) does not imply that it can be used indiscriminately; some characters are associated with contextual rules that must be applied as well.

The information given in this section is provided to make the rules, tables, and protocol easier to understand. The normative generating rules that correspond to this informal discussion appear in [[IDNA2008-Tables](#)] and the rules that actually determine what labels can be registered or looked up are in [[IDNA2008-Protocol](#)].

#### [3.1.](#) A Tiered Model of Permitted Characters and Labels

Moving to an inclusion model requires respecifying the list of characters that are permitted in IDNs. In IDNA2003, the role and utility of characters are independent of context and fixed forever (or until the standard is replaced). Making completely context-independent rules globally has proven impractical because some characters, especially those that are called "Join\_Controls" in Unicode, are needed to make reasonable use of some scripts but have no visible effect(s) in others. IDNA2003 prohibited those types of characters entirely. But the restrictions led to a consensus that under some conditions, these "joiner" characters were legitimately needed to allow useful mnemonics for some languages and scripts. The requirement to support those characters but limit their use to very specific contexts was reinforced by the observation that handling of

particular characters across the languages that use a script, or the use of similar or identical-looking characters in different scripts, is more complex than many people believed it was several years ago.

Independently of the characters chosen (see next subsection), the approach is to divide the characters that appear in Unicode into three categories:

### 3.1.1. PROTOCOL-VALID

Characters identified as "PROTOCOL-VALID" (often abbreviated "PVALID") are, in general, permitted by IDNA for all uses in IDNs. Their use may be restricted by rules about the context in which they appear or by other rules that apply to the entire label in which they are to be embedded. For example, any label that contains a character in this category that has a "right-to-left" property must be used in context with the "Bidi" rules (see [[IDNA2008-Bidi](#)]).

The term "PROTOCOL-VALID" is used to stress the fact that the presence of a character in this category does not imply that a given registry need accept registrations containing any of the characters in the category. Registries are still expected to apply judgment about labels they will accept and to maintain rules consistent with those judgments (see [[IDNA2008-Protocol](#)] and [Section 3.3](#)).

Characters that are placed in the "PROTOCOL-VALID" category are expected to never be removed from it or reclassified. While theoretically characters could be removed from Unicode, such removal would be inconsistent with the Unicode stability principles (see [[Unicode51](#)], [Appendix F](#)) and hence should never occur.

### 3.1.2. Characters Valid Only in Context With Others

Some characters may be unsuitable for general use in IDNs but necessary for the plausible support of some scripts. The two most commonly-cited examples are the zero-width joiner and non-joiner characters (ZWJ, U+200D and ZWNJ, U+200C), but provisions for unambiguous labels may require that other characters be restricted to particular contexts. For example, the ASCII hyphen is not permitted to start or end a label, whether that label contains non-ASCII

characters or not.

#### [3.1.2.1.](#) Contextual Restrictions

These characters must not appear in IDNs without additional restrictions, typically because they have no visible consequences in most scripts but affect format or presentation in a few others or because they are combining characters that are safe for use only in conjunction with particular characters or scripts. In order to permit them to be used at all, they are specially identified as "CONTEXTUAL RULE REQUIRED" and, when adequately understood, associated with a rule. In addition, the rule will define whether it is to be applied on lookup as well as registration. A distinction is made between characters that indicate or prohibit joining (known as "CONTEXT-JOINER" or "CONTEXTJ") and other characters requiring contextual treatment ("CONTEXT-OTHER" or "CONTEXT0"). Only the

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former require full testing at lookup time.

It is important to note that these contextual rules cannot prevent all uses of the relevant characters that might be confusing or problematic. What they are expected to do is to confine applicability of the characters to scripts (and narrower contexts) where zone administrators are knowledgeable enough about the use of those characters to be prepared to deal with them appropriately. For example, a registry dealing with an Indic script that requires ZWJ and/or ZWNJ as part of the writing system is expected to understand where the characters have visible effect and where they do not and to make registration rules accordingly. By contrast, a registry dealing with Latin or Cyrillic script might not be actively aware that the characters exist, much less about the consequences of embedding them in labels drawn from those scripts.

#### [3.1.2.2.](#) Rules and Their Application

The actual rules may be DEFINED or NULL. If present, they may have values of "True" (character may be used in any position in any label), "False" (character may not be used in any label), or may be a set of procedural rules that specify the context in which the character is permitted.

Examples of descriptions of typical rules, stated informally and in

English, include "Must follow a character from Script XYZ", "Must occur only if the entire label is in Script ABC", "Must occur only if the previous and subsequent characters have the DFG property".

Because it is easier to identify these characters than to know that they are actually needed in IDNs or how to establish exactly the right rules for each one, a rule may have a null value in a given version of the tables. Characters associated with null rules are not permitted to appear in putative labels for either registration or lookup. Of course, a later version of the tables might contain a non-null rule.

The description of the syntax of the rules, and the rules themselves, appears in [[IDNA2008-Tables](#)]. [[anchor11: ??? Section number would be good here.]]

### [3.1.3](#). DISALLOWED

Some characters are inappropriate for use in IDNs and are thus excluded for both registration and lookup (i.e., IDNA-conforming applications performing name lookup should verify that these characters are absent; if they are present, the label strings should be rejected rather than converted to A-labels and looked up. Some of

these characters are problematic for use in IDNs (such as the FRACTION SLASH character, U+2044), while some of them (such as the various HEART symbols, e.g., U+2665, U+2661, and U+2765, see [Section 7.6](#)) simply fall outside the conventions for typical identifiers (basically letters and numbers).

Of course, this category would include code points that had been removed entirely from Unicode should such removals ever occur.

Characters that are placed in the "DISALLOWED" category are expected to never be removed from it or reclassified. If a character is classified as "DISALLOWED" in error and the error is sufficiently problematic, the only recourse would be either to introduce a new code point into Unicode and classify it as "PROTOCOL-VALID" or for the IETF to accept the considerable costs of an incompatible change and replace the relevant RFC with one containing appropriate exceptions.

There is provision for exception cases but, in general, characters are placed into "DISALLOWED" if they fall into one or more of the following groups:

- o The character is a compatibility equivalent for another character. In slightly more precise Unicode terms, application of normalization method NFKC to the character yields some other character.
- o The character is an upper-case form or some other form that is mapped to another character by Unicode casefolding.
- o The character is a symbol or punctuation form or, more generally, something that is not a letter, digit, or a mark that is used to form a letter or digit.

#### [3.1.4.](#) UNASSIGNED

For convenience in processing and table-building, code points that do not have assigned values in a given version of Unicode are treated as belonging to a special UNASSIGNED category. Such code points are prohibited in labels to be registered or looked up. The category differs from DISALLOWED in that code points are moved out of it by the simple expedient of being assigned in a later version of Unicode (at which point, they are classified into one of the other categories as appropriate).

The rationale for restricting the processing of UNASSIGNED characters is simply that if such characters were permitted to be looked up, for example, and were later assigned, but subject to some set of

contextual rules, un-updated instances of IDNA-aware software might permit lookup of labels containing the previously-unassigned characters while updated versions of IDNA-aware software might restrict their use in lookup, depending on the contextual rules. It should be clear that under no circumstance should an UNASSIGNED character be permitted in a label to be registered as part of a domain name.

#### [3.2.](#) Registration Policy

While these recommendations cannot and should not define registry

policies, registries should develop and apply additional restrictions as needed to reduce confusion and other problems. For example, it is generally believed that labels containing characters from more than one script are a bad practice although there may be some important exceptions to that principle. Some registries may choose to restrict registrations to characters drawn from a very small number of scripts. For many scripts, the use of variant techniques such as those as described in [RFC 3843](#) [[RFC3743](#)] and [RFC 4290](#) [[RFC4290](#)], and illustrated for Chinese by the tables described in [RFC 4713](#) [[RFC4713](#)] may be helpful in reducing problems that might be perceived by users.

In general, users will benefit if registries only permit characters from scripts that are well-understood by the registry or its advisers. If a registry decides to reduce opportunities for confusion by constructing policies that disallow characters used in historic writing systems or characters whose use is restricted to specialized, highly technical contexts, some relevant information may be found in [Section 2.4](#) "Specific Character Adjustments", Table 4 "Candidate Characters for Exclusion from Identifiers" of [[Unicode-UAX31](#)] and [Section 3.1](#). "General Security Profile for Identifiers" in [[Unicode-Security](#)].

It is worth stressing that these principles of policy development and application apply at all levels of the DNS, not only, e.g., TLD or SLD registrations and that even a trivial, "anything permitted that is valid under the protocol" policy is helpful in that it helps users and application developers know what to expect.

### [3.3](#). Layered Restrictions: Tables, Context, Registration, Applications

The essence of the character rules in IDNA2008 is based on the realization that there is no single magic bullet for any of the issues associated with a multiscrypt DNS. Instead, the specifications define a variety of approaches that, together, constitute multiple lines of defense against ambiguity in identifiers and loss of referential integrity. The actual character tables are the first mechanism, protocol rules about how those characters are

applied or restricted in context are the second, and those two in combination constitute the limits of what can be done by a protocol alone. As discussed in the previous section ([Section 3.2](#)), registries are expected to restrict what they permit to be



registered, devising and using rules that are designed to optimize the balance between confusion and risk on the one hand and maximum expressiveness in mnemonics on the other.

In addition, there is an important role for user agents in warning against label forms that appear problematic given their knowledge of local contexts and conventions. Of course, no approach based on naming or identifiers alone can protect against all threats.

## [4.](#) Issues that Constrain Possible Solutions

### [4.1.](#) Display and Network Order

The correct treatment of domain names requires a clear distinction between Network Order (the order in which the code points are sent in protocols) and Display Order (the order in which the code points are displayed on a screen or paper). The order of labels in a domain name that contains characters that are normally written right to left is discussed in [[IDNA2008-Bidi](#)]. In particular, there are questions about the order in which labels are displayed if left to right and right to left labels are adjacent to each other, especially if there are also multiple consecutive appearances of one of the types. The decision about the display order is ultimately under the control of user agents --including web browsers, mail clients, and the like-- which may be highly localized. Even when formats are specified by protocols, the full composition of an Internationalized Resource Identifier (IRI) [[RFC3987](#)] or Internationalized Email address contains elements other than the domain name. For example, IRIs contain protocol identifiers and field delimiter syntax such as "http://" or "mailto:" while email addresses contain the "@" to separate local parts from domain names. User agents are not required to use those protocol-based forms directly but often do so. While display, parsing, and processing within a label is specified by the normative documents in the IDNA2008 collection, the relationship between fully-qualified domain names and internationalized labels is unchanged from the base DNS specifications. Comments in this document about such full domain names are explanatory or examples of what might be done and must not be considered normative.

Questions remain about protocol constraints implying that the overall direction of these strings will always be left to right (or right to left) for an IRI or email address, or if they even should conform to such rules. These questions also have several possible answers.

Should a domain name abc.def, in which both labels are represented in scripts that are written right to left, be displayed as fed.cba or cba.fed? An IRI for clear text web access would, in network order, begin with "http://" and the characters will appear as "http://abc.def" -- but what does this suggest about the display order? When entering a URI to many browsers, it may be possible to provide only the domain name and leave the "http://" to be filled in by default, assuming no tail (an approach that does not work for protocols other than HTTP or whatever is chosen as the default). The natural display order for the typed domain name on a right to left system is fed.cba. Does this change if a protocol identifier, tail, and the corresponding delimiters are specified?

While logic, precedent, and reality suggest that these are questions for user interface design, not IETF protocol specifications, experience in the 1980s and 1990s with mixing systems in which domain name labels were read in network order (left to right) and those in which those labels were read right to left would predict a great deal of confusion, and heuristics that sometimes fail, if each implementation of each application makes its own decisions on these issues.

Any version of IDNA, including the current one, must be written in terms of the network (transmission on the wire) order of characters in labels and for the labels in complete (fully-qualified) domain names and must be quite precise about those relationships. While some strong suggestions about display order would be desirable to reduce the chances for inconsistent transcription of domain names from printed form, such suggestions are beyond the scope of these specifications.

#### [4.2.](#) Entry and Display in Applications

Applications can accept domain names using any character set or sets desired by the application developer, specified by the operating system, or dictated by other constraints, and can display domain names in any character set or character coding system. That is, the IDNA protocol does not affect the interface between users and applications.

An IDNA-aware application can accept and display internationalized domain names in two formats: the internationalized character set(s) supported by the application (i.e., an appropriate local representation of a U-label), and as an A-label. Applications may allow the display of A-labels, but are encouraged to not do so except as an interface for special purposes, possibly for debugging, or to cope with display limitations. In general, they should allow, but

not encourage, user input of that label form. A-labels are opaque

and ugly and malicious variations on them are not easily detected by users. Where possible, they should thus only be exposed to users and in contexts in which they are absolutely needed. Because IDN labels can be rendered either as A-labels or U-labels, the application may reasonably have an option for the user to select the preferred method of display; if it does, rendering the U-label should normally be the default.

Domain names are often stored and transported in many places. For example, they are part of documents such as mail messages and web pages. They are transported in many parts of many protocols, such as both the control commands of SMTP and associated the message body parts, and in the headers and the body content in HTTP. It is important to remember that domain names appear both in domain name slots and in the content that is passed over protocols.

In protocols and document formats that define how to handle specification or negotiation of charsets, labels can be encoded in any charset allowed by the protocol or document format. If a protocol or document format only allows one charset, the labels must be given in that charset. Of course, not all charsets can properly represent all labels. If a U-label cannot be displayed in its entirety, the only choice (without loss of information) may be to display the A-label.

In any place where a protocol or document format allows transmission of the characters in internationalized labels, labels should be transmitted using whatever character encoding and escape mechanism the protocol or document format uses at that place. This provision is intended to prevent situations in which, e.g., UTF-8 domain names appear embedded in text that is otherwise in some other character coding.

All protocols that use domain name slots (See [Section 2.3.1.6](#) [[anchor14: ?? Verify this]] in [\[IDNA2008-Defs\]](#)) already have the capacity for handling domain names in the ASCII charset. Thus, A-labels can inherently be handled by those protocols.

#### [4.3.](#) Linguistic Expectations: Ligatures, Digraphs, and Alternate Character Forms

[[anchor15: There is some internal redundancy and repetition in the material in this section. Specific suggestions about to reduce or eliminate redundant text would be appreciated. If no such suggestions are received before -07 is posted, this note will be removed.]]

Users often have expectations about character matching or equivalence

that are based on their own languages and the orthography of those languages. These expectations may not be consistent with forms or actions that can be naturally accommodated in a character coding system, especially if multiple languages are written using the same script but using different conventions. A Norwegian user might expect a label with the ae-ligature to be treated as the same label as one using the Swedish spelling with a-diaeresis even though applying that mapping to English would be astonishing to users. A user in German might expect a label with an o-umlaut and a label that had "oe" substituted, but was otherwise the same, treated as equivalent even though that substitution would be a clear error in Swedish. A Chinese user might expect automatic matching of Simplified and Traditional Chinese characters, but applying that matching for Korean or Japanese text would create considerable confusion. For that matter, an English user might expect "theater" and "theatre" to match.

Related issues arise because there are a number of languages written with alphabetic scripts in which single phonemes are written using two characters, termed a "digraph", for example, the "ph" in "pharmacy" and "telephone". (Note that characters paired in this manner can also appear consecutively without forming a digraph, as in "tophat".) Certain digraphs are normally indicated typographically by setting the two characters closer together than they would be if used consecutively to represent different phonemes. Some digraphs are fully joined as ligatures (strictly designating setting totally without intervening white space, although the term is sometimes applied to close set pairs). An example of this may be seen when the word "encyclopaedia" is set with a U+00E6 LATIN SMALL LIGATURE AE (and some would not consider that word correctly spelled unless the ligature form was used or the "a" was dropped entirely). When these ligature and digraph forms have the same interpretation across all languages that use a given script, application of Unicode

normalization generally resolves the differences and causes them to match. When they have different interpretations, any requirements for matching must utilize other methods, presumably at the registry level, or users must be educated to understand that matching will not occur.

Difficulties arise from the fact that a given ligature may be a completely optional typographic convenience for representing a digraph in one language (as in the above example with some spelling conventions), while in another language it is a single character that may not always be correctly representable by a two-letter sequence (as in the above example with different spelling conventions). This can be illustrated by many words in the Norwegian language, where the "ae" ligature is the 27th letter of a 29-letter extended Latin alphabet. It is equivalent to the 28th letter of the Swedish

alphabet (also containing 29 letters), U+00E4 LATIN SMALL LETTER A WITH DIAERESIS, for which an "ae" cannot be substituted according to current orthographic standards.

That character (U+00E4) is also part of the German alphabet where, unlike in the Nordic languages, the two-character sequence "ae" is usually treated as a fully acceptable alternate orthography for the "umlauted a" character. The inverse is however not true, and those two characters cannot necessarily be combined into an "umlauted a". This also applies to another German character, the "umlauted o" (U+00F6 LATIN SMALL LETTER O WITH DIAERESIS) which, for example, cannot be used for writing the name of the author "Goethe". It is also a letter in the Swedish alphabet where, like the "a with diaeresis", it cannot be correctly represented as "oe" and in the Norwegian alphabet, where it is represented, not as "o with diaeresis", but as "slashed o", U+00F8.

Some of the ligatures that have explicit code points in Unicode were given special handling in IDNA2003 and now pose additional problems in transition. See [Section 7.2](#).

Additional cases with alphabets written right to left are described in [Section 4.5](#).

Whether ligatures and digraphs are to be treated as a sequence of characters or as a single standalone one constitute a problem that

cannot be resolved solely by operating on scripts. They are, however, a key concern in the IDN context. Their satisfactory resolution will require support in policies set by registries, which therefore need to be particularly mindful not just of this specific issue, but of all other related matters that cannot be dealt with on an exclusively algorithmic and global basis.

Just as with the examples of different-looking characters that may be assumed to be the same, it is in general impossible to deal with these situations in a system such as IDNA -- or with Unicode normalization generally -- since determining what to do requires information about the language being used, context, or both. Consequently, these specifications make no attempt to treat these combined characters in any special way. However, their existence provides a prime example of a situation in which a registry that is aware of the language context in which labels are to be registered, and where that language sometimes (or always) treats the two-character sequences as equivalent to the combined form, should give serious consideration to applying a "variant" model [[RFC3743](#)] [[RFC4290](#)], or to prohibiting registration of one the forms entirely, to reduce the opportunities for user confusion and fraud that would result from the related strings being registered to different

parties.

[[anchor16: Placeholder: A discussion of the Arabic digit issue should go here once it is resolved in some appropriate way.]]

#### [4.4.](#) Case Mapping and Related Issues

In the DNS, ASCII letters are stored with their case preserved. Matching during the query process is case-independent, but none of the information that might be represented by choices of case has been lost. That model has been accidentally helpful because, as people have created DNS labels by catenating words (or parts of words) to form labels, case has often been used to distinguish among components and make the labels more memorable.

The solution of keeping the characters separate but doing matching independent of case is not feasible with IDNA or any IDNA-like model because the matching would then have to be done on the server rather than have characters mapped on the client. That situation was

recognized in IDNA2003 and nothing in these specifications fundamentally changes it or could do so. In IDNA2003, all characters are case-folded and mapped. That results in upper-case characters being mapped to lower-case ones and in some other transformations of alternate forms of characters, especially those that do not have (or did not have) upper-case forms. For example, Greek Final Form Sigma (U+03C2) is mapped to the medial form (U+03C3) and Eszett (German Sharp S, U+00DF) is mapped to "ss". Neither of these mappings is reversible because the upper case of U+03C3 is the Upper Case Sigma (U+03A3) and "ss" is an ASCII string. IDNA2008 permits, at the risk of some incompatibility, slightly more flexibility in this area by avoid case folding and treating these characters as themselves. Approaches to handling that incompatibility are discussed in [Section 7.2](#). Although information is lost in IDNA2003's ToASCII operation so that, in some sense, neither Final Sigma nor Eszett can be represented in an IDN at all, its guarantee of mapping when those characters are used as input can be interpreted as violating one of the conditions discussed in [Section 7.4.1](#) and hence requiring a prefix change. The consensus was to not make a prefix change in spite of this issue. Of course, had a prefix change been made (at the costs discussed in [Section 7.4.3](#)) there would have been several options, including, if desired, assignment of the character to the CONTEXTUAL RULE REQUIRED category and requiring that it only be used in carefully-selected contexts.

#### [4.5](#). Right to Left Text

In order to be sure that the directionality of right to left text is unambiguous, IDNA2003 required that any label in which right to left

characters appear both starts and ends with them, not include any characters with strong left to right properties (which excludes other alphabetic characters but permits European digits), and rejects any other string that contains a right to left character. This is one of the few places where the IDNA algorithms (both in IDNA2003 and in IDAN2008) are required to examine an entire label, not just individual characters. The algorithmic model used in IDNA2003 rejects the label when the final character in a right to left string requires a combining mark in order to be correctly represented.

That prohibition is not acceptable for writing systems for languages written with consonantal alphabets to which diacritical vocalic

systems are applied, and for languages with orthographies derived from them where the combining marks may have different functionality. In both cases the combining marks can be essential components of the orthography. Examples of this are Yiddish, written with an extended Hebrew script, and Dhivehi (the official language of Maldives) which is written in the Thaana script (which is, in turn, derived from the Arabic script). IDNA2008 removes the restriction on final combining characters with a new set of rules for right to left scripts and their characters. Those new rules are specified in [[IDNA2008-Bidi](#)].

## [5.](#) IDNs and the Robustness Principle

The model of IDNs described in this document can be seen as a particular instance of the "Robustness Principle" that has been so important to other aspects of Internet protocol design. This principle is often stated as "Be conservative about what you send and liberal in what you accept" (See, e.g., [Section 1.2.2](#) of the applications-layer Host Requirements specification [[RFC1123](#)]). For IDNs to work well, not only must the protocol be carefully designed and implemented, but zone administrators (registries) must have and require sensible policies about what is registered -- conservative policies -- and implement and enforce them.

Conversely, lookup applications are expected to reject labels that clearly violate global (protocol) rules (no one has ever seriously claimed that being liberal in what is accepted requires being stupid). However, once one gets past such global rules and deals with anything sensitive to script or locale, it is necessary to assume that garbage has not been placed into the DNS, i.e., one must be liberal about what one is willing to look up in the DNS rather than guessing about whether it should have been permitted to be registered.

As mentioned elsewhere, if a string cannot be successfully found in the DNS after the lookup processing described here, it makes no

difference whether it simply wasn't registered or was prohibited by some rule at the registry. Applications should, however, be sensitive to the fact that, because of the possibility of DNS wildcards, the ability to successfully resolve a name does not guarantee that it was actually registered.



If lookup applications, as a user interface (UI) or other local matter, decide to warn about some strings that are valid under the global rules but that they perceive as dangerous, that is their prerogative and we can only hope that the market (and maybe regulators) will reinforce the good choices and discourage the poor ones. In this context, a lookup application that decides a string that is valid under the protocol is dangerous and refuses to look it up is in violation of the protocols; one that is willing to look something up, but warns against it, is exercising a local choice.

## 6. Front-end and User Interface Processing for Lookup

Domain names may be identified and processed in many contexts. They may be typed in by users either by themselves or embedded in an identifier structured for a particular protocol or class of protocols such as email addresses, URIs, or IRIs. They may occur in running text or be processed by one system after being provided in another. Systems may wish to try to normalize URLs so as to determine (or guess) whether a reference is valid or two references point to the same object without actually looking the objects up and comparing them (that is necessary, not just a choice, for URI types that are not intended to be resolved). Some of these goals may be more easily and reliably satisfied than others. While there are strong arguments for any domain name that is placed "on the wire" -- transmitted between systems -- to be in the zero-ambiguity forms of A-labels, it is inevitable that programs that process domain names will encounter U-labels or variant forms.

One source of such forms will be labels created under IDNA2003 because that protocol allowed labels that were transformed from native-character format by mapping some characters into others before conversion into ACE ("xn--...") format. One consequence of the transformations was that, when the ToUnicode and ToASCII operations of IDNA2003 were applied, ToUnicode(ToASCII(original-label)) often did not produce the original label. IDNA2008 explicitly defines A-labels and U-labels as different forms of the same abstract label, forms that are stable when conversions are performed between them (without mappings). A different way of explaining this is that there are, today, domain names in files on the Internet that use characters that cannot be represented directly in, or recovered from, (A-label) domain names but for which interpretations are provided by IDNA2003.

There are two major categories of such characters, those that are removed by NFKC normalization and those upper-case characters that are mapped to lower-case (there are also a few characters that are given special-case mapping treatment in Stringprep, including lower-case characters that are case-folded into other lower-case characters or strings).

Other issues in domain name identification and processing arise because IDNA2003 specified that several other characters be treated as equivalent to the ASCII period (dot, full stop) character used as a label separator. If a string that might be a domain name appears in an arbitrary context (such as running text), it is difficult, even with only ASCII characters, to know whether an actual domain name (or a protocol parameter like a URI) is present and where it starts and ends. When using Unicode, this gets even more difficult if treatment of certain special characters (like the dot that separates labels in a domain name) depends on context (e.g., prior knowledge of whether the string represents a domain name or not). That knowledge is not available if the primary heuristic for identifying the presence of domain names in strings depends on the presence of dots separating groups of characters with no intervening spaces.

As discussed elsewhere in this document, the IDNA2008 model removes all of these mappings and interpretations, including the equivalence of different forms of dots, from the protocol, discouraging such mappings and leaving them, when necessary, to local processing. This should not be taken to imply that local processing is optional or can be avoided entirely, even if doing so might have been desirable in a world without IDNA2003 IDNs in files and archives. Instead, unless the program context is such that it is known that any IDNs that appear will contain either U-label or A-label forms, or that other forms can safely be rejected, some local processing of apparent domain name strings will be required, both to maintain compatibility with IDNA2003 and to prevent user astonishment. Such local processing, while not specified in this document or the associated ones, will generally take one of two forms:

- o Generic Preprocessing.

When the context in which the program or system that processes domain names operates is global, a reasonable balance must be found that is sensitive to the broad range of local needs and assumptions while, at the same time, not sacrificing the needs of one language, script, or user population to those of another.

For this case, the best practice will usually be to apply NFKC and case-mapping (or, perhaps better yet, Stringprep itself), plus dot-mapping where appropriate, to the domain name string prior to applying IDNA. That practice will not only yield a reasonable

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compromise of user experience with protocol requirements but will be almost completely compatible with the various forms permitted by IDNA2003.

- o Highly Localized Preprocessing.

Unlike the case above, there will be some situations in which software will be highly localized for a particular environment and carefully adapted to the expectations of users in that environment. The many discussions about using the Internet to preserve and support local cultures suggest that these cases may be more common in the future than they have been so far.

In these cases, we should avoid trying to tell implementers what they should accept, if only because they are quite likely (and for good reason) to ignore us. We would assume that they would map characters that the intuitions of their users would suggest be mapped and would hope that they would do that mapping as early as possible, storing A-label or U-label forms in files and transporting only those forms between systems. One can imagine switches about whether some sorts of mappings occur, warnings before applying them or, in a slightly more extreme version of the approach taken in Internet Explorer version 7 (IE7), systems that utterly refuse to handle "strange" characters at all if they appear in U-label form. None of those local decisions are a threat to interoperability as long as (i) only U-labels and A-labels are used in interchange with systems outside the local environment, (ii) no character that would be valid in a U-label as itself is mapped to something else, (iii) any local mappings are applied as a preprocessing step (or, for conversions from U-labels or A-labels to presentation forms, postprocessing), not as part of IDNA processing proper, and (iv) appropriate consideration is given to labels that might have entered the environment in conformance to IDNA2003.

In either case, it is vital that user interface designs and, where the interfaces are not sufficient, users, be aware that the only forms of domain names that this protocol anticipates will resolve globally or compare equal when crude methods (i.e., those not conforming to the strict definition of label equivalence given in [\[IDNA2008-Defs\]](#)) are used are those in which all native-script labels are in U-label form. Forms that assume mapping will occur, especially forms that were not valid under IDNA2003, may or may not

function in predictable ways across all implementations.

User interfaces involving Latin-based scripts should take special care when considering how to handle case mapping because small differences in label strings may cause behavior that is astonishing to users. Because case-insensitive comparison is done for ASCII

strings by DNS-servers, an all-ASCII label is treated as case-insensitive. However, if even one of the characters of that string is replaced by one that requires the label to be given IDN treatment (e.g., by adding a diacritical mark), then the label effectively becomes case-sensitive because only lower-case characters are permitted in IDNs. This suggests that case mapping for Latin-based scripts (and possibly other scripts with case distinctions) as a preprocessing matter in applications may be wise to prevent user astonishment, but, since all applications may not do this and ambiguity in transport is not desirable, the that case-dependent forms should not be stored in files.

The comments above apply only in operations that look up names or interpret files. There are several reasons why registration activities should require final names and verification of those names by the would-be registrant.

## [7.](#) Migration from IDNA2003 and Unicode Version Synchronization

### [7.1.](#) Design Criteria

As mentioned above and in [RFC 4690](#), two key goals of the IDNA2008 design are to enable applications to be agnostic about whether they are being run in environments supporting any Unicode version from 3.2 onward and to permit incrementally adding new characters, character groups, scripts, and other character collections as they are incorporated into Unicode, without disruption and, in the long term, without "heavy" processes such as those involving IETF consensus. (An IETF consensus process is required by the IDNA2008 specifications and is expected to be required and used until significant experience accumulates with IDNA operations and new versions of Unicode.) The mechanisms that support this are outlined above and elsewhere in the IDNA2008 document set, but this section reviews them in a context that may be more helpful to those who need to understand the approach

and make plans for it.

#### [7.1.1.](#) General IDNA Validity Criteria

The general criteria for a putative label, and the collection of characters that make it up, to be considered IDNA-valid are (the actual rules are rigorously defined in the "Protocol" and "Tables" documents):

- o The characters are "letters", marks needed to form letters, numerals, or other code points used to write words in some language. Symbols, drawing characters, and various notational characters are intended to be permanently excluded -- some because

they are harmful in URI, IRI, or similar contexts (e.g., characters that appear to be slashes or other reserved URI punctuation) and others because there is no evidence that they are important enough to Internet operations or internationalization to justify expansion of domain names beyond the general principle of "letters, digits, and hyphen" and the complexities that would come with it (additional discussion and rationale for the symbol decision appears in [Section 7.6](#)).

- o Other than in very exceptional cases, e.g., where they are needed to write substantially any word of a given language, punctuation characters are excluded as well. The fact that a word exists is not proof that it should be usable in a DNS label and DNS labels are not expected to be usable for multiple-word phrases (although they are certainly not prohibited if the conventions and orthography of a particular language cause that to be possible). Even for English, very common constructions -- contractions like "don't" or "it's", names that are written with apostrophes such as "O'Reilly", or characters for which apostrophes are common substitutes cannot be represented in DNS labels. Words in English whose usually-preferred spellings include diacritical marks cannot be represented under the original hostname rules, but most can be represented if treated as IDNs.
- o Characters that are unassigned (have no character assignment at all) in the version of Unicode being used by the registry or application are not permitted, even on lookup. The issues involved in this decision are discussed in [Section 7.7](#).

- o Any character that is mapped to another character by a current version of NFKC is prohibited as input to IDNA (for either registration or lookup). With a few exceptions, this principle excludes any character mapped to another by Nameprep [[RFC3491](#)].

Tables used to identify the characters that are IDNA-valid are expected to be driven by the principles above, principles that are specified exactly in [[IDNA2008-Tables](#)]). The rules given there are normative, rather than being just an interpretation of the tables.

### [7.1.2](#). Labels in Registration

Anyone entering a label into a DNS zone must properly validate that label -- i.e., be sure that the criteria for that label are met -- in order for applications to work as intended. This principle is not new. For example, since the DNS was first deployed, zone administrators have been expected to verify that names meet "hostname" [[RFC0952](#)] where necessary for the expected applications. Later addition of special service location formats [[RFC2782](#)] imposed

new requirements on zone administrators for the use of labels that conform to the requirements of those formats. For zones that will contain IDNs, support for Unicode version-independence requires restrictions on all strings placed in the zone. In particular, for such zones:

- o Any label that appears to be an A-label, i.e., any label that starts in "xn--", must be IDNA-valid, i.e., they must be valid A-labels, as discussed in [Section 2](#) above.
- o The Unicode tables (i.e., tables of code points, character classes, and properties) and IDNA tables (i.e., tables of contextual rules such as those that appear in the Tables document), must be consistent on the systems performing or validating labels to be registered. Note that this does not require that tables reflect the latest version of Unicode, only that all tables used on a given system are consistent with each other.

Under this model, a registry (or entity communicating with a registry to accomplish name registrations) will need to update its tables --

both the Unicode-associated tables and the tables of permitted IDN characters -- to enable a new script or other set of new characters. It will not be affected by newer versions of Unicode, or newly-authorized characters, until and unless it wishes to make those registrations. The zone administrator is also responsible -- under the protocol and to registrants and users -- for both checking as required by the protocol and verification that whatever policies it develops are complied with, whether those policies are for minimizing risks due to confusable characters and sequences, for preserving language or script integrity, or for other purposes. Those checking and verification procedures are more extensive than those that are expected of applications systems that look names up.

Systems looking up or resolving DNS labels, especially IDN DNS labels, must be able to assume that applicable registration rules were followed for names entered into the DNS.

### [7.1.3.](#) Labels in Lookup

Anyone looking up a label in a DNS zone is required to

- o Maintain a consistent set of tables, as discussed above. As with registration, the tables need not reflect the latest version of Unicode but they must be consistent.
- o Validate the characters in labels to be looked up only to the extent of determining that the U-label does not contain either

code points prohibited by IDNA (categorized as "DISALLOWED") or code points that are unassigned in its version of Unicode.

- o Validate the label itself for conformance with a small number of whole-label rules, notably verifying that there are no leading combining marks, that the "bidi" conditions are met if right to left characters appear, that any required contextual rules are available and that, if such rules are associated with Joiner Controls, they are tested.
- o Avoid validating other contextual rules about characters, including mixed-script label prohibitions, although such rules may be used to influence presentation decisions in the user interface. [[anchor20: Check this, and all similar statements, against

Protocol when that is finished.]]

By avoiding applying its own interpretation of which labels are valid as a means of rejecting lookup attempts, the lookup application becomes less sensitive to version incompatibilities with the particular zone registry associated with the domain name.

An application or client that processes names according to this protocol and then resolves them in the DNS will be able to locate any name that is validly registered, as long as its version of the Unicode-associated tables is sufficiently up-to-date to interpret all of the characters in the label. Messages to users should distinguish between "label contains an unallocated code point" and other types of lookup failures. A failure on the basis of an old version of Unicode may lead the user to a desire to upgrade to a newer version, but will have no other ill effects (this is consistent with behavior in the transition to the DNS when some hosts could not yet handle some forms of names or record types).

## [7.2.](#) Changes in Character Interpretations

[[anchor21: Note in Draft: This subsection is completely new in version -04 and has been further tuned in -05 and -06 of this document. It could almost certainly use improvement, although this note will be removed if there are not significant suggestions about the -06 version. It also contains some material that is redundant with material in other sections. I have not tried to remove that material and will not do so until the WG concludes that this section is relatively stable, but would appreciate help in identifying what should be removed or how this might be enhanced to contain more of that other material. --JcK]]

In those scripts that make case distinctions, there are a few characters for which an obvious and unique upper case character has

not historically been available to match a lower case one or vice versa. For those characters, the mappings used in constructing the Stringprep tables for IDNA2003, performed using the Unicode CaseFold operation (See [Section 5.8](#) of the Unicode Standard [[Unicode51](#)]), generate different characters or sets of characters. Those operations are not reversible and lose even more information than traditional upper case or lower case transformations, but are more



useful than those transformations for comparison purposes. Two notable characters of this type are the German character Eszett (Sharp S, U+00DF) and the Greek Final Form Sigma (U+03C2). The former is case-folded to the ASCII string "ss", the latter to a medial (Lower Case) Sigma (U+03C3).

The decision to eliminate mappings, including case folding, from the IDNA2008 protocol in order to make A-labels and U-labels idempotent made these characters problematic. If they were to be disallowed, important words and mnemonics could not be written in orthographically reasonable ways. If they were to be permitted as characters distinct from the forms produced by case folding, there would be no information loss and registries would have maximum flexibility, but labels using those characters that were looked up according to IDNA2003 rules would be transformed into A-labels using their case-mapped variations while lookup according to IDNA2008 rules would be based on different A-labels that represented the actual characters.

With the understanding that there would be incompatibility either way but a judgment that the incompatibility was not significant enough to just a prefix change, the WG concluded that Eszett and Final Form Sigma should be treated as distinct and Protocol-Valid characters.

The decision faces registries, especially registries maintaining zones for third parties, with a variation on what has become a familiar problem: how to introduce a new service in a way that does not create confusion or significantly weaken or invalidate existing identifiers.

There have traditionally been several approaches to problems of this type. Without any preference or claim to completeness, these are:

- o Do not permit use of the newly-available character at the registry level. This might cause lookup failures if a domain name were to be written with the expectation of the IDNA2003 mapping behavior, but would eliminate any possibility of false matches.
- o Hold a "sunrise"-like arrangement in which holders of the previously-mapped labels (labels containing "ss" in the Eszett case or ones containing Lower Case Sigma in the Final Sigma case)

are given priority (and perhaps other benefits) for registering the corresponding string containing the newly-available characters.

- o Adopt some sort of "variant" approach in which registrants either obtained labels with both character forms or one of them was blocked from registration by anyone but the registrant of the other form.

In principle, lookup applications could also compensate for the difference in interpretation by looking up the string according to the interpretation specified in these documents and then, if that failed, doing the lookup with the mapping, simulating the IDNA2003 interpretation. The risk of false positives is such that this is generally to be discouraged unless the application is able to engage in a "is this what you meant" dialogue with the end user.

### [7.3.](#) More Flexibility in User Agents

These documents do not specify mappings between one character or code point and others for any reason. Instead, they prohibit the characters that would be mapped to others by normalization, upper case to lower case changes, or other rules. As examples, while mathematical characters based on Latin ones are accepted as input to IDNA2003, they are prohibited in IDNA2008. Similarly, double-width characters and other variations are prohibited as IDNA input.

Since the rules in [[IDNA2008-Tables](#)] have the effect that only strings that are not transformed by NFKC are valid, if an application chooses to perform NFKC normalization before lookup, that operation is safe since this will never make the application unable to look up any valid string. However, as discussed above, the application cannot guarantee that any other application will perform that mapping, so it should be used only with caution and for informed users.

In many cases these prohibitions should have no effect on what the user can type as input to the lookup process. It is perfectly reasonable for systems that support user interfaces to perform some character mapping that is appropriate to the local environment. This would normally be done prior to actual invocation of IDNA. At least conceptually, the mapping would be part of the Unicode conversions discussed above and in [[IDNA2008-Protocol](#)]. However, those changes will be local ones only -- local to environments in which users will clearly understand that the character forms are equivalent. For use in interchange among systems, it appears to be much more important that U-labels and A-labels can be mapped back and forth without loss of information.

One specific, and very important, instance of this strategy arises with case-folding. In the ASCII-only DNS, names are looked up and matched in a case-independent way, but no actual case-folding occurs. Names can be placed in the DNS in either upper or lower case form (or any mixture of them) and that form is preserved, returned in queries, and so on. IDNA2003 simulated that behavior for non-ASCII strings by performing case-folding at registration time (resulting in only lower-case IDNs in the DNS) and when names were looked up.

As suggested earlier in this section, it appears to be desirable to do as little character mapping as possible consistent with having Unicode work correctly (e.g., NFC mapping to resolve different codings for the same character is still necessary although the specifications require that it be performed prior to invoking the protocol) and to make the mapping between A-labels and U-labels idempotent. Case-mapping is not an exception to this principle. If only lower case characters can be registered in the DNS (i.e., be present in a U-label), then IDNA2008 should prohibit upper-case characters as input (and therefore does so). Some other considerations reinforce this conclusion. For example, an essential element of the ASCII case-mapping functions is that, for individual characters, `uppercase(character)` must be equal to `uppercase(lowercase(character))`. That requirement may not be satisfied with IDNs. For example, there are some characters in scripts that use case distinction that do not have counterparts in one case or the other. The relationship between upper case and lower case may even be language-dependent, with different languages (or even the same language in different areas) expecting different mappings. Of course, the expectations of users who are accustomed to a case-insensitive DNS environment will probably be well-served if user agents perform case folding prior to IDNA processing, but the IDNA procedures themselves should neither require such mapping nor expect them when they are not natural to the localized environment.

#### 7.4. The Question of Prefix Changes

The conditions that would require a change in the IDNA ACE prefix ("xn--" for the version of IDNA specified in [\[RFC3490\]](#)) have been a great concern to the community. A prefix change would clearly be necessary if the algorithms were modified in a manner that would create serious ambiguities during subsequent transition in registrations. This section summarizes our conclusions about the conditions under which changes in prefix would be necessary and the

implications of such a change.

#### [7.4.1.](#) Conditions Requiring a Prefix Change

An IDN prefix change is needed if a given string would be looked up or otherwise interpreted differently depending on the version of the protocol or tables being used. Consequently, work to update IDNs would require a prefix change if, and only if, one of the following four conditions were met:

1. The conversion of an A-label to Unicode (i.e., a U-label) yields one string under IDNA2003 ([RFC3490](#)) and a different string under IDNA2008.
2. An input string that is valid under IDNA2003 and also valid under IDNA2008 yields two different A-labels with the different versions of IDNA. This condition is believed to be essentially equivalent to the one above except for a very small number of edge cases which may not, pragmatically, justify a prefix change (See [Section 7.2](#)).

Note, however, that if the input string is valid under one version and not valid under the other, this condition does not apply. See the first item in [Section 7.4.2](#), below.

3. A fundamental change is made to the semantics of the string that is inserted in the DNS, e.g., if a decision were made to try to include language or specific script information in that string, rather than having it be just a string of characters.
4. A sufficiently large number of characters is added to Unicode so that the Punycode mechanism for block offsets no longer has enough capacity to reference the higher-numbered planes and blocks. This condition is unlikely even in the long term and certain not to arise in the next few years.

#### [7.4.2.](#) Conditions Not Requiring a Prefix Change

In particular, as a result of the principles described above, none of the following changes require a new prefix:

1. Prohibition of some characters as input to IDNA. This may make names that are now registered inaccessible, but does not require a prefix change.
2. Adjustments in IDNA tables or actions, including normalization definitions, that affect characters that were already invalid under IDNA2003.

3. Changes in the style of the IDNA definition that does not alter the actions performed by IDNA.

#### [7.4.3.](#) Implications of Prefix Changes

While it might be possible to make a prefix change, the costs of such a change are considerable. Even if they wanted to do so, registries could not convert all IDNA2003 ("xn--") registrations to a new form at the same time and synchronize that change with applications supporting lookup. Unless all existing registrations were simply to be declared invalid (and perhaps even then) systems that needed to support both labels with old prefixes and labels with new ones would first process a putative label under the IDNA2008 rules and try to look it up and then, if it were not found, would process the label under IDNA2003 rules and look it up again. That process could significantly slow down all processing that involved IDNs in the DNS especially since, in principle, a fully-qualified name could contain a mixture of labels that were registered with the old and new prefixes, a situation that would make the use of DNS caching very difficult. In addition, looking up the same input string as two separate A-labels would create some potential for confusion and attacks, since they could, in principle, map to different targets and then resolve to different entries in the DNS.

Consequently, a prefix change is to be avoided if at all possible, even if it means accepting some IDNA2003 decisions about character distinctions as irreversible and/or giving special treatment to edge cases.

## [7.5.](#) Stringprep Changes and Compatibility

The Nameprep [[RFC3491](#)] specification, a key part of IDNA2003, is a profile of Stringprep [[RFC3454](#)]. While Nameprep is a Stringprep profile specific to IDNA, Stringprep is used by a number of other protocols. Concerns have been expressed about problems for non-DNS uses of Stringprep being caused by changes to the specification intended to improve the handling of IDNs, most notably as this might affect identification and authentication protocols. The proposed new inclusion tables [[IDNA2008-Tables](#)], the reduction in the number of characters permitted as input for registration or lookup ([Section 3](#)), and even the proposed changes in handling of right to left strings [[IDNA2008-Bidi](#)] either give interpretations to strings prohibited under IDNA2003 or prohibit strings that IDNA2003 permitted. The IDNA2008 protocol does not use either Nameprep or Stringprep at all, so there are no side-effect changes to other protocols.

It is particularly important to keep IDNA processing separate from processing for various security protocols because some of the

constraints that are necessary for smooth and comprehensible use of IDNs may be unwanted or undesirable in other contexts. For example, the criteria for good passwords or passphrases are very different from those for desirable IDNs: passwords should be hard to guess, while domain names should normally be easily memorable. Similarly, internationalized SCSI identifiers and other protocol components are likely to have different requirements than IDNs.

## [7.6.](#) The Symbol Question

One of the major differences between this specification and the original version of IDNA is that the original version permitted non-letter symbols of various sorts, including punctuation and line-drawing symbols, in the protocol. They were always discouraged in practice. In particular, both the "IESG Statement" about IDNA and all versions of the ICANN Guidelines specify that only language characters be used in labels. This specification disallows symbols entirely. There are several reasons for this, which include:

- o As discussed elsewhere, the original IDNA specification assumed that as many Unicode characters as possible should be permitted, directly or via mapping to other characters, in IDNs. This

specification operates on an inclusion model, extrapolating from the LDH rules -- which have served the Internet very well -- to a Unicode base rather than an ASCII base.

- o Most Unicode names for letters are, in most cases, fairly intuitive, unambiguous and recognizable to users of the relevant script. Symbol names are more problematic because there may be no general agreement on whether a particular glyph matches a symbol; there are no uniform conventions for naming; variations such as outline, solid, and shaded forms may or may not exist; and so on. As just one example, consider a "heart" symbol as it might appear in a logo that might be read as "I love...". While the user might read such a logo as "I love..." or "I heart...", considerable knowledge of the coding distinctions made in Unicode is needed to know that there more than one "heart" character (e.g., U+2665, U+2661, and U+2765) and how to describe it. These issues are of particular importance if strings are expected to be understood or transcribed by the listener after being read out loud.  
[[anchor22: The above paragraph remains controversial as to whether it is valid. The WG will need to make a decision if this section is not dropped entirely.]]
- o Consider the case of a screen reader used by blind Internet users who must listen to renderings of IDN domain names and possibly reproduce them on the keyboard.

- o As a simplified example of this, assume one wanted to use a "heart" or "star" symbol in a label. This is problematic because those names are ambiguous in the Unicode system of naming (the actual Unicode names require far more qualification). A user or would-be registrant has no way to know -- absent careful study of the code tables -- whether it is ambiguous (e.g., where there are multiple "heart" characters) or not. Conversely, the user seeing the hypothetical label doesn't know whether to read it -- try to transmit it to a colleague by voice -- as "heart", as "love", as "black heart", or as any of the other examples below.
- o The actual situation is even worse than this. There is no possible way for a normal, casual, user to tell the difference between the hearts of U+2665 and U+2765 and the stars of U+2606 and U+2729 or the without somehow knowing to look for a

distinction. We have a white heart (U+2661) and few black hearts. Consequently, describing a label as containing a heart hopelessly ambiguous: we can only know that it contains one of several characters that look like hearts or have "heart" in their names. In cities where "Square" is a popular part of a location name, one might well want to use a square symbol in a label as well and there are far more squares of various flavors in Unicode than there are hearts or stars.

- o The consequence of these ambiguities of description and dependencies on distinctions that were, or were not, made in Unicode codings is that symbols are a very poor basis for reliable communication. Consistent with this conclusion, the Unicode standard recommends that strings used in identifiers not contain symbols or punctuation [[Unicode-UAX31](#)]. Of course, these difficulties with symbols do not arise with actual pictographic languages and scripts which would be treated like any other language characters; the two should not be confused.

#### [7.7](#). Migration Between Unicode Versions: Unassigned Code Points

In IDNA2003, labels containing unassigned code points are looked up on the assumption that, if they appear in labels and can be mapped and then resolved, the relevant standards must have changed and the registry has properly allocated only assigned values.

In the protocol as described in these documents, strings containing unassigned code points must not be either looked up or registered. There are several reasons for this, with the most important ones being:

- o It cannot be known in advance, and with sufficient reliability, that a code point that was not previously assigned will not be assigned to a compatibility character or one that would be otherwise disallowed by the rules in [[IDNA2008-Tables](#)]. In IDNA2003, since there is no direct dependency on NFKC (Stringprep's tables are based on NFKC, but IDNA2003 depends only on Stringprep), allocation of a compatibility character might produce some odd situations, but it would not be a problem. In



IDNA2008, where compatibility characters are assigned to DISALLOWED unless character-specific exceptions are made, permitting strings containing unassigned characters to be looked up would permit violating the principle that characters in DISALLOWED are not looked up.

- o The Unicode Standard specifies that an unassigned code point normalizes (and, where relevant, case folds) to itself. If the code point is later assigned to a character, and particularly if the newly-assigned code point has a combining class that determines its placement relative to other combining characters, it could normalize to some other code point or sequence, creating confusion and/or violating other rules listed here.
- o Tests involving the context of characters (e.g., some characters being permitted only adjacent to ones of specific types but otherwise invisible or very problematic for other reasons) and integrity tests on complete labels are needed. Unassigned code points cannot be permitted because one cannot determine whether particular code points will require contextual rules (and what those rules should be) before characters are assigned to them and the properties of those characters fully understood.
- o More generally, the status of an unassigned character with regard to the DISALLOWED and PROTOCOL-VALID categories, and whether contextual rules are required with the latter, cannot be evaluated until a character is actually assigned and known. By contrast, characters that are actually DISALLOWED are placed in that category only as a consequence of rules applied to known properties or per-character evaluation.

Another way to look at this is that permitting an unassigned character to be looked up is nearly equivalent to reclassifying a character from DISALLOWED to PROTOCOL-VALID since different systems will interpret the character in different ways.

It is possible to argue that the issues above are not important and that, as a consequence, it is better to retain the principle of looking up labels even if they contain unassigned characters because all of the important scripts and characters have been coded as of

obscure characters or archaic scripts. Unfortunately, that does not appear to be a safe assumption for at least two reasons. First, much the same claim of completeness has been made for earlier versions of Unicode. The reality is that a script that is obscure to much of the world may still be very important to those who use it. Cultural and linguistic preservation principles make it inappropriate to declare the script of no importance in IDNs. Second, we already have counterexamples in, e.g., the relationships associated with new Han characters being added (whether in the BMP or in Unicode Plane 2).

## [7.8.](#) Other Compatibility Issues

The 2003 IDNA model includes several odd artifacts of the context in which it was developed. Many, if not all, of these are potential avenues for exploits, especially if the registration process permits "source" names (names that have not been processed through IDNA and Nameprep) to be registered. As one example, since the character Eszett, used in German, is mapped by IDNA2003 into the sequence "ss" rather than being retained as itself or prohibited, a string containing that character but that is otherwise in ASCII is not really an IDN (in the U-label sense defined above) at all. After Nameprep maps the Eszett out, the result is an ASCII string and so does not get an xn-- prefix, but the string that can be displayed to a user appears to be an IDN. The newer version of the protocol eliminates this artifact. A character is either permitted as itself or it is prohibited; special cases that make sense only in a particular linguistic or cultural context can be dealt with as localization matters where appropriate.

## [8.](#) Name Server Considerations

### [8.1.](#) Processing Non-ASCII Strings

Existing DNS servers do not know the IDNA rules for handling non-ASCII forms of IDNs, and therefore need to be shielded from them. All existing channels through which names can enter a DNS server database (for example, master files (as described in [RFC 1034](#)) and DNS update messages [[RFC2136](#)]) are IDN-unaware because they predate IDNA. Other sections of this document provide the needed shielding by ensuring that internationalized domain names entering DNS server databases through such channels have already been converted to their equivalent ASCII A-label forms.

Because of the distinction made between the algorithms for Registration and Lookup in [[IDNA2008-Protocol](#)] (a domain name containing only ASCII codepoints can not be converted to an A-label),

there can not be more than one A-label form for any given U-label.

As specified in [RFC 2181](#) [RFC2181], the DNS protocol explicitly allows domain labels to contain octets beyond the ASCII range (0000..007F), and this document does not change that. Note, however, that there is no defined interpretation of octets 0080..00FF as characters. If labels containing these octets are returned to applications, unpredictable behavior could result. The A-label form, which cannot contain those characters, is the only standard representation for internationalized labels in the DNS protocol.

### [8.2.](#) DNSSEC Authentication of IDN Domain Names

DNS Security (DNSSEC) [RFC2535] is a method for supplying cryptographic verification information along with DNS messages. Public Key Cryptography is used in conjunction with digital signatures to provide a means for a requester of domain information to authenticate the source of the data. This ensures that it can be traced back to a trusted source, either directly or via a chain of trust linking the source of the information to the top of the DNS hierarchy.

IDNA specifies that all internationalized domain names served by DNS servers that cannot be represented directly in ASCII MUST use the A-label form. Conversion to A-labels MUST be performed prior to a zone being signed by the private key for that zone. Because of this ordering, it is important to recognize that DNSSEC authenticates a domain name containing A-labels or conventional LDH-labels, not U-labels. In the presence of DNSSEC, no form of a zone file or query response that contains a U-label may be signed or the signature validated.

One consequence of this for sites deploying IDNA in the presence of DNSSEC is that any special purpose proxies or forwarders used to transform user input into IDNs must be earlier in the lookup flow than DNSSEC authenticating nameservers for DNSSEC to work.

### [8.3.](#) Root and other DNS Server Considerations

IDNs in A-label form will generally be somewhat longer than current domain names, so the bandwidth needed by the root servers is likely to go up by a small amount. Also, queries and responses for IDNs will probably be somewhat longer than typical queries historically, so EDNS0 [RFC2671] support may be more important (otherwise, queries and responses may be forced to go to TCP instead of UDP).

## [9.](#) Internationalization Considerations

DNS labels and fully-qualified domain names provide mnemonics that assist in identifying and referring to resources on the Internet. IDNs expand the range of those mnemonics to include those based on languages and character sets other than Western European and Roman-derived ones. But domain "names" are not, in general, words in any language. The recommendations of the IETF policy on character sets and languages, [BCP 18](#) [[RFC2277](#)] are applicable to situations in which language identification is used to provide language-specific contexts. The DNS is, by contrast, global and international and ultimately has nothing to do with languages. Adding languages (or similar context) to IDNs generally, or to DNS matching in particular, would imply context dependent matching in DNS, which would be a very significant change to the DNS protocol itself. It would also imply that users would need to identify the language associated with a particular label in order to look that label up, a decision that would be impossible in many or most cases.

## [10.](#) IANA Considerations

This section gives an overview of registries required for IDNA. The actual definitions of the first two appear in [[IDNA2008-Tables](#)].

### [10.1.](#) IDNA Character Registry

The distinction among the three major categories "UNASSIGNED", "DISALLOWED", and "PROTOCOL-VALID" is made by special categories and rules that are integral elements of [[IDNA2008-Tables](#)]. Convenience in programming and validation requires a registry of characters and scripts and their categories, updated for each new version of Unicode and the characters it contains. The details of this registry are specified in [[IDNA2008-Tables](#)].

### [10.2.](#) IDNA Context Registry

For characters that are defined in the IDNA Character Registry list as PROTOCOL-VALID but requiring a contextual rule (i.e., the types of

rule described in [Section 3.1.2](#)), IANA will create and maintain a list of approved contextual rules. The details for those rules appear in [[IDNA2008-Tables](#)].

### [10.3](#). IANA Repository of IDN Practices of TLDs

This registry, historically described as the "IANA Language Character Set Registry" or "IANA Script Registry" (both somewhat misleading terms) is maintained by IANA at the request of ICANN. It is used to

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provide a central documentation repository of the IDN policies used by top level domain (TLD) registries who volunteer to contribute to it and is used in conjunction with ICANN Guidelines for IDN use.

It is not an IETF-managed registry and, while the protocol changes specified here may call for some revisions to the tables, these specifications have no direct effect on that registry and no IANA action is required as a result.

## [11](#). Security Considerations

### [11.1](#). General Security Issues with IDNA

This document in the IDNA2008 series is purely explanatory and informational and consequently introduces no new security issues. It would, of course, be a poor idea for someone to try to implement from it; such an attempt would almost certainly lead to interoperability problems and might lead to security ones. A discussion of security issues with IDNA, including some relevant history, appears in [[IDNA2008-Defs](#)].

## [12](#). Acknowledgments

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A meeting was held on 30 January 2008 to attempt to reconcile differences in perspective and terminology about this set of specifications between the design team and members of the Unicode Technical Consortium. The discussions at and subsequent to that meeting were very helpful in focusing the issues and in refining the specifications. The active participants at that meeting were (in alphabetic order as usual) Harald Alvestrand, Vint Cerf, Tina Dam, Mark Davis, Lisa Dusseault, Patrik Faltstrom (by telephone), Cary Karp, John Klensin, Warren Kumari, Lisa Moore, Erik van der Poel, Michel Suignard, and Ken Whistler. We express our thanks to Google

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for support of that meeting and to the participants for their contributions.

Useful comments and text on the WG versions of the draft were received from many participants in the IETF "IDNABIS" WG and a number of document changes resulted from mailing list discussions made by that group. Marcos Sanz provided specific analysis and suggestions that were exceptionally helpful in refining the text, as did Vint Cerf, Mark Davis, Martin Duerst, Ken Whistler, and Andrew Sullivan.

### [13.](#) Contributors

While the listed editor held the pen, this core of this document and the initial WG version represents the joint work and conclusions of an ad hoc design team consisting of the editor and, in alphabetic order, Harald Alvestrand, Tina Dam, Patrik Faltstrom, and Cary Karp. In addition, there were many specific contributions and helpful comments from those listed in the Acknowledgments section and others who have contributed to the development and use of the IDNA protocols.

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## [Appendix A](#). Change Log

[ [ RFC Editor: Please remove this appendix. ] ]

### [A.1](#). Changes between Version -00 and Version -01 of [draft-ietf-idnabis-rationale](#)

- o Clarified the U-label definition to note that U-labels must contain at least one non-ASCII character. Also clarified the relationship among label types.

- o Rewrote the discussion of Labels in Registration ([Section 7.1.2](#)) and related text about IDNA-validity (in the "Defs" document as of -04 of this one) to narrow its focus and remove more general restrictions. Added a temporary note in line to explain the situation.
- o Changed the "IDNA uses Unicode" statement to focus on compatibility with IDNA2003 and avoid more general or controversial assertions.
- o Added a discussion of examples to [Section 7.1](#)
- o Made a number of other small editorial changes and corrections suggested by Mark Davis.
- o Added several more discussion anchors and notes and expanded or updated some existing ones.

#### [A.2.](#) Version -02

- o Trimmed change log, removing information about pre-WG drafts.
- o Adjusted discussion of Contextual Rules to match the new location of the tables and some conceptual material.
- o Rewrote the material on preprocessing somewhat.
- o Moved the material about relationships with IDNA2003 to be part of a single section on transitions.
- o Removed several placeholders and made editorial changes in accordance with decisions made at IETF 72 in Dublin and not disputed on the mailing list.

#### [A.3.](#) Version -03

This special update to the Rationale document is intended to try to get the discussion of what is normative or not under control. While the IETF does not normally annotate individual sections of documents with whether they are normative or not, concerns that we don't know which is which, claims that some material is normative that would be problematic if so classified, etc., argue that we should at least be able to have a clear discussion on the subject.

Two annotations have been applied to sections that might reasonably be considered normative. One annotation is based on the list of sections in Mark Davis's note of 29 September (<http://>

The other is based on an elaboration of John Klensin's response on 7 October (<http://www.alvestrand.no/pipermail/idna-update/2008-October/002691.html>). These should just be considered two suggestions to illuminate and, one hopes, advance the Working Group's discussions.

Some additional editorial changes have been made, but they are basically trivial. In the editor's judgment, it is not possible to make significantly more progress with this document until the matter of document organization is settled.

#### [A.4.](#) Version -04

- o Definitional and other normative material moved to new document ([draft-ietf-idnabis-defs](#)). Version -03 annotations removed.
- o Material on differences between IDNA2003 and IDNA2008 moved to an appendix in Protocol.
- o Material left over from the origins of this document as a preliminary proposal has been removed or rewritten.
- o Changes made to reflect consensus call results, including removing several placeholder notes for discussion.
- o Added more material, including discussion of historic scripts, to [Section 3.2](#) on registration policies.
- o Added a new section ([Section 7.2](#)) to contain specific discussion of handling of characters that are interpreted differently in input to IDNA2003 and 2008.
- o Some material, including this section/appendix, rearranged.

#### [A.5.](#) Version -05

- o Many small editorial changes, including changes to eliminate the last vestiges of what appeared to be 2119 language (upper-case MUST, SHOULD, or MAY) and small adjustments to terminology.

#### [A.6.](#) Version -06

- o Removed Security Considerations material and pointed to Defs, where it now appears as of version 05.
- o Started changing uses of "IDNA2008" in running text to "in these specifications" or the equivalent. These documents are titled simply "IDNA"; once they are standardized, "the current version" may be a more appropriate reference than one containing a year.

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As discussed on the mailing list, we can and should discuss how to refer to these documents at an appropriate time (e.g., when we know when we will be finished) but, in the interim, it seems appropriate to simply start getting rid of the version-specific terminology where it can naturally be removed.

- o Additional discussion of mappings, etc., especially for case-sensitivity.
- o Clarified relationship to base DNS specifications.
- o Consolidated discussion of lookup of unassigned characters.
- o More editorial fine-tuning.

#### [A.7.](#) Version -07

- o Revised terminology by adding terms: NR-LDH-label, Invalid-A-label (or False-A-label), R-LDH-label, valid IDNA-label in [Section 1.3.3](#).
- o Moved the "name server considerations" material to this document from Protocol because it is non-normative and not part of the protocol itself.
- o To improve clarity, redid discussion of the reasons why looking up unassigned code points is prohibited.
- o Editorial and other non-substantive corrections to reflect earlier errors as well as new definitions and terminology.

#### [A.8.](#) Version -08

- o Slight revision to "contextual" discussion ([Section 3.1.2](#)) and moving it to a separate subsection, rather than under "PVALID", for better parallelism with Tables. Also reflected Mark's comments about the limitations of the approach.
- o Added placeholder notes as reminders of where references to the other documents need Section numbers. More of these will be added as needed (feel free to identify relevant places), but the actual section numbers will not be inserted until the documents are completely stable, i.e., on their way to the RFC Editor.

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