      Review and Recommendations for Internationalized Domain Names (IDNs)

Status of This Memo

Copyright Notice

Abstract

   This note describes issues raised by the deployment and use of
   Internationalized Domain Names. It describes problems both at the
   time of registration and for use of those names in the DNS. It
   recommends that IETF should update the RFCs relating to IDNs and a
   framework to be followed in doing so, as well as summarizing and
   identifying some work that is required outside the IETF. In
   particular, it proposes that some changes be investigated for the
   Internationalizing Domain Names in Applications (IDNA) standard and
   its supporting tables, based on experience gained since those
   standards were completed.

Table of Contents

1. Introduction

1.1. The Role of IDNs and This Document

   While IDNs have been advocated as the solution to a wide range of
   problems, this document is written from the perspective that they are
   no more and no less than DNS names, reflecting the same requirements
   for use, stability, and accuracy as traditional "hostnames", but
   using a much larger collection of permitted characters. In
   particular, while IDNs represent a step toward an Internet that is
   equally accessible from all languages and scripts, they, at best,
   address only a small part of that very broad objective. There has
   been controversy since IDNs were first suggested about how important
   they will actually turn out to be; that controversy will probably
   continue. Accessibility from all languages is an important
   objective, hence it is important that our standards and definitions
   for IDNs be smoothly adaptable to additional scripts as they are
   added to the Unicode character set.

   The utility of IDNs must be evaluated in terms of their application
   by users and in protocols: the ability to simply put a name into the
   DNS and retrieve it is not, in and of itself, important. From this
   point of view, IDNs will be useful and effective if they provide
   stable and predictable references -- references that are no less
   stable and predictable, and no less secure, than their ASCII
   counterparts.

   This combination of objectives and criteria has proven very difficult
   to satisfy. Experience in developing the IDNA standard and during
   the initial years of its implementation and deployment suggests that
   it may be impossible to fully satisfy all of them and that
   engineering compromises are needed to yield a result that is
   workable, even if not completely satisfactory. Based on that
   experience and issues that have been raised, it is now appropriate to
   review some of the implications of IDNs, the decisions made in
   defining them, and the foundation on which they rest and determine
   whether changes are needed and, if so, which ones.

   The design of the DNS itself imposes some additional constraints. If
   the DNS is to remain globally interoperable, there are specific
   characteristics that no implementation of IDNs, or the DNS more
   generally, can change. For example, because the DNS is a global
   hierarchal administrative namespace with only a single name at any
   given node, there is one and only one owner of each domain name.
   Also, when strings are looked up in the DNS, positive responses can
   only reflect exact matches: if there is no exact match, then one gets
   an error reply, not a list of near matches or other supplemental
   information. Searches and approximate matchings are not possible.

Finally, because the DNS is a distributed system where any server
might cache responses, and later use those cached responses to
attempt to satisfy queries before a global lookup is done, every
server must use the same matching criteria.

1.2. Status of This Document and Its Recommendations

This document reviews the IDN landscape from an IETF perspective and
presents the recommendations and conclusions of the IAB, based
partially on input from an ad hoc committee charged with reviewing
IDN issues and the path forward (see Section 7). Its recommendations
are advice to the IETF, or in a few cases to other bodies, for topics
to be investigated and actions to be taken if those bodies, after
their examinations, consider those actions appropriate.

1.3. The IDNA Standard

During 2002, the IETF completed the following RFCs that, together,
define IDNs:

RFC 3454 Preparation of Internationalized Strings ("Stringprep")
   [RFC3454].
   Stringprep is a generic mechanism for taking a Unicode string and
   converting it into a canonical format. Stringprep itself is just
   a collection of rules, tables, and operations. Any protocol or
   algorithm that uses it must define a "Stringprep profile", which
   specifies which of those rules are applied, how, and with which
   characteristics.

RFC 3490 Internationalizing Domain Names in Applications (IDNA)
   [RFC3490].
   IDNA is the base specification in this group. It specifies that
   Nameprep is used as the Stringprep profile for domain names, and
   that Punycode is the relevant encoding mechanism for use in
   generating an ASCII-compatible ("ACE") form of the name. It also
   applies some additional conversions and character filtering that
   are not part of Nameprep.

RFC 3491 Nameprep: A Stringprep Profile for Internationalized Domain
   Names (IDN) [RFC3491].
   Nameprep is designed to meet the specific needs of IDNs and, in
   particular, to support case-folding for scripts that support what
   are traditionally known as upper- and lowercase forms of the same
   letters. The result of the Nameprep algorithm is a string
   containing a subset of the Unicode Character set, normalized and
   case-folded so that case-insensitive comparison can be made.

RFC 3492 Punycode: A Bootstring encoding of Unicode for
     Internationalized Domain Names in Applications (IDNA) [RFC3492].
     Punycode is a mechanism for encoding a Unicode string in ASCII
     characters. The characters used are the same the subset of
     characters that are allowed in the hostname definition of DNS,
     i.e., the "letter, digit, and hyphen" characters, sometimes known
     as "LDH".

1.4. Unicode Documents

   Unicode is used as the base, and defining, character set for IDNs.
   Unicode is standardized by the Unicode Consortium, and synchronized
   with ISO to create ISO/IEC 10646 [ISO10646]. At the time the RFCs
   mentioned earlier were created, Unicode was at Version 3.2. For
   reasons explained later, it was necessary to pick a particular,
   then-current, version of Unicode when IDNA was adopted.
   Consequently, the RFCs are explicitly dependent on Unicode Version
   3.2 [Unicode32]. There is, at present, no established mechanism for
   modifying the IDNA RFCs to use newer Unicode versions (see
   Section 3.1).

   Unicode is a very large and complex character set. (The term
   "character set" or "charset" is used in a way that is peculiar to the
   IETF and may not be the same as the usage in other bodies and
   contexts.) The Unicode Standard and related documents are created
   and maintained by the Unicode Technical Committee (UTC), one of the
   committees of the Unicode Consortium.

   The Consortium first published The Unicode Standard [Unicode10] in
   1991, and continues to develop standards based on that original work.
   Unicode is developed in conjunction with the International
   Organization for Standardization, and it shares its character
   repertoire with ISO/IEC 10646. Unicode and ISO/IEC 10646 function
   equivalently as character encodings, but The Unicode Standard
   contains much more information for implementers, covering -- in depth
   -- topics such as bitwise encoding, collation, and rendering. The
   Unicode Standard enumerates a multitude of character properties,
   including those needed for supporting bidirectional text. The
   Unicode Consortium and ISO standards do use slightly different
   terminology.

1.5. Definitions

   The following terms and their meanings are critical to understanding
   the rest of this document and to discussions of IDNs more generally.
   These terms are derived from [RFC3536], which contains additional
   discussion of some of them.

1.5.1. Language

   A language is a way that humans interact. The use of language occurs
   in many forms, including speech, writing, and signing.

   Some languages have a close relationship between the written and
   spoken forms, while others have a looser relationship. RFC 3066
   [RFC3066] discusses languages in more detail and provides identifiers
   for languages for use in Internet protocols. Computer languages are
   explicitly excluded from this definition. The most recent IETF work
   in this area, and on script identification (see below), is documented
   in [RFC4645] and [RFC4646].

1.5.2. Script

   A script is a set of graphic characters used for the written form of
   one or more languages. This definition is the one used in
   [ISO10646].

   Examples of scripts are Arabic, Cyrillic, Greek, Han (the so-called
   ideographs used in writing Chinese, Japanese, and Korean), and
   "Latin". Arabic, Greek, and Latin are, of course, also names of
   languages.

   Historically, the script that is known as "Latin" in Unicode and most
   contexts associated with information technology standards is known in
   the linguistic community as "Roman" or "Roman-derived". The latter
   terminology distinguishes between the Latin language and the
   characters used to write it, especially in Republican times, from the
   much richer and more decorated script derived and adapted from those
   characters. Since IDNA is defined using Unicode and that standard
   used the term "LATIN" in its character names and descriptions, that
   terminology will be used in this document as well except when
   "Roman-derived" is needed for clarity. However, readers approaching
   this document from a cultural or linguistic standpoint should be
   aware that the use of, or references to, "Latin script" in this
   document refers to the entire collection of Roman-derived characters,
   not just the characters used to write the Latin language. Some other
   issues with script identification and relationships with other
   standards are discussed in [RFC4646].

1.5.3. Multilingual

   The term "multilingual" has many widely-varying definitions and thus
   is not recommended for use in standards. Some of the definitions
   relate to the ability to handle international characters; other
   definitions relate to the ability to handle multiple charsets; and
   still others relate to the ability to handle multiple languages.

While this term has been deprecated for IETF-related uses and does
not otherwise appear in this document, a discussion here seemed
appropriate since the term is still widely used in some discussions
of IDNs.

1.5.4. Localization

Localization is the process of adapting an internationalized
application platform or application to a specific cultural
environment. In localization, the same semantics are preserved while
the syntax or presentation forms may be changed.

Localization is the act of tailoring an application for a different
language or script or culture. Some internationalized applications
can handle a wide variety of languages. Typical users understand
only a small number of languages, so the program must be tailored to
interact with users in just the languages they know.

Somewhat different definitions for localization and
internationalization (see below) are used by groups other than the
IETF. See [W3C-Localization] for one example.

1.5.5. Internationalization

In the IETF, the term "internationalization" is used to describe
adding or improving the handling of non-ASCII text in a protocol.
Other bodies use the term in other ways, often with subtle variation
in meaning. The term "internationalization" is often abbreviated
"i18n" (and localization as "l10n").

Many protocols that handle text only handle the characters associated
with one script (often, a subset of the characters used in writing
English text), or leave the question of what character set is used up
to local guesswork (which leads to interoperability problems).
Adding non-ASCII text to such a protocol allows the protocol to
handle more scripts, with the intention of being able to include all
of the scripts that are useful in the world. It is naive (sic) to
believe that all English words can be written in ASCII, various
mythologies notwithstanding.

1.6. Statements and Guidelines

When the IDNA RFCs were published, the IESG and ICANN made statements
that were intended to guide deployment and future work. In recent
months, ICANN has updated its statement and others have also made
contributions. It is worth noting that the quality of understanding
of internationalization issues as applied to the DNS has evolved

considerably over the last few years. Organizations that took
specific positions a year or more ago might not make exactly the same
statements today.

1.6.1. IESG Statement

The IESG made a statement on IDNA [IESG-IDN]:

IDNA, through its requirement of Nameprep [RFC3491], uses
equivalence tables that are based only on the characters
themselves; no attention is paid to the intended language (if any)
for the domain name. However, for many domain names, the intended
language of one or more parts of the domain name actually does
matter to the users.

Similarly, many names cannot be presented and used without
ambiguity unless the scripts to which their characters belong are
known. In both cases, this additional information should be of
concern to the registry.

The statement is longer than this, but these paragraphs are the
important ones. The rest of the statement consists of explanations
and examples.

1.6.2. ICANN Statements

1.6.2.1. Initial ICANN Guidelines

Soon after the IDNA standards were adopted, ICANN produced an initial
version of its "IDN Guidelines" [ICANNv1]. This document was
intended to serve two purposes. The first was to provide a basis for
releasing the Generic Top Level Domain (gTLD) registries that had
been established by ICANN from a contractual restriction on the
registration of labels containing hyphens in the third and fourth
positions. The second was to provide a general framework for the
development of registry policies for the implementation of IDNs.

One of the key components of this framework prescribed strict
compliance with RFCs 3490, 3491, and 3492. With the framework, ICANN
specified that IDNA was to be the sole mechanism to be used in the
DNS to represent IDNs.

Limitations on the characters available for inclusion in IDNs were
mandated by two mechanisms. The first was by requiring an
"inclusion-based approach (meaning that code points that are not
explicitly permitted by the registry are prohibited) for identifying
permissible

code points from among the full Unicode repertoire." The second
mechanism required the association of every IDN with a specific
language, with additional policies also being language based:

"In implementing the IDN standards, top-level domain registries will
(a) associate each registered internationalized domain name with one
language or set of languages,
(b) employ language-specific registration and administration rules
that are documented and publicly available, such as the reservation
of all domain names with equivalent character variants in the
languages associated with the registered domain name, and,
(c) where the registry finds that the registration and administration
rules for a given language would benefit from a character variants
table, allow registrations in that language only when an appropriate
table is available. ... In implementing the IDN standards, top-level
domain registries should, at least initially, limit any given domain
label (such as a second-level domain name) to the characters
associated with one language or set of languages only."

It was left to each TLD registry to define the character repertoire
it would associate with any given language. This led to significant
variation from registry to registry, with further heterogeneity in
the underlying language-based IDN policies. If the guidelines had
made provision for IDN policies also being based on script, a
substantial amount of the resulting ambiguity could have been
avoided. However, they did not, and the sequence of events leading
to the present review of IDNA was thus triggered.

1.6.2.2. ICANN Version 2 Guidelines

One of the responses of the TLD registries to what was widely
perceived as a crisis situation was to invoke the mechanism described
in the initial guidelines: "As the deployment of IDNs proceeds, ICANN
and the IDN registries will review these Guidelines at regular
intervals, and revise them as necessary based on experience."

The pivotal requirement was the modification of the guidelines to
permit script-based policies for IDNs. Further concern was expressed
about the need for realistically implementable mechanisms for the
propagation of TLD registry policies into the lower levels of their
name trees. In addition to the anticipated increase of constraint on
the protocol level, one obvious additional approach would be to
replace the guidelines by an instrument that itself had clear status
in the IETF's normative framework. A BCP was therefore seen as the
appropriate focus for longer-term effort. The most pressing issues
would be dealt with in the interim by incremental modification to the
guidelines, but no need was seen for the detailed further development
of those guidelines once that incremental modification was complete.

The outcome of this action was a version 2.0 of the guidelines
[ICANNv2], which was endorsed by the ICANN Board on November 8, 2005
for a period of nine months. The Board stated further that it "tasks
the IDN working group to continue its important work and return to
the board with specific IDN improvement recommendations before the
ICANN Meeting in Morocco" and "supports the working group's continued
action to reframe the guidelines completely in a manner appropriate
for further development as a Best Current Practices (BCP) document,
to ensure that the Guideline directions will be used deeper into the
DNS hierarchy and within TLD's where ICANN has a lesser policy
relationship."

Retaining the inclusion-based approach established in version 1.0,
the crucial addition to the policy framework is that:

"All code points in a single label will be taken from the same script
as determined by the Unicode Standard Annex #24: Script Names at
http://www.unicode.org/reports/tr24. Exception to this is
permissible for languages with established orthographies and
conventions that require the commingled use of multiple scripts. In
such cases, visually confusable characters from different scripts
will not be allowed to coexist in a single set of permissible
codepoints unless a corresponding policy and character table is
clearly defined."

Additionally:

"Permissible code points will not include: (a) line symbol-drawing
characters (as those in the Unicode Box Drawing block), (b) symbols
and icons that are neither alphanumeric nor ideographic language
characters, such as typographic and pictographic dingbats, (c)
characters with well-established functions as protocol elements, (d)
punctuation marks used solely to indicate the structure of
sentences."

Attention has been called to several points that are not adequately
dealt with (if at all) in the version 2.0 guidelines but that ought
to be included in the policy framework without waiting for the
production and release of a document based on a "best practices"
model. The term "BCP" above does not necessarily refer to an IETF
consensus document.

The intention in November 2005 was for the recommended major revision
to be put to the ICANN Board prior to its meeting in Morocco (in late
June 2006), but for the changes to be collated incrementally and
appear in interim version 2.n releases of the guidelines. The IAB's
understanding is that, while there has been some progress with this,

other issues relating to IDNs subsequently diverted much of the
energy that was intended to be devoted to the more extensive
treatment of the guidelines.

2. General Problems and Issues

   This section interweaves problems and issues of several types. Each
   subsection outlines something that is perceived to be a problem or
   issue "with IDNs", therefore needing correction. Some of these
   issues can be at least partially resolved by making changes to
   elements of the IDNA protocol or tables. Others will exist as long
   as people have expectations of IDNs that are inconsistent with the
   basic DNS architecture. It is important to identify this entire
   range of problems because users, registrants, and policy makers often
   do not understand the protocol and other technical issues but only
   the difference between what they believe happens or should happen and
   what actually happens. As long as those differences exist, there
   will be demands for functionality or policy changes for IDNs. Of
   course, some of these demands will be less realistic than others, but
   even the realistic ones should be understood in the same context as
   the others.

   Most of the issues that have been raised, and that are discussed in
   this document, exist whether IDNA remains tied to Unicode 3.2 or
   whether migration to new Unicode versions is contemplated. A
   migration path is necessary to accommodate newly-coded scripts and to
   permit the maximum number of languages and scripts to be represented
   in domain names. However, the migration issues are largely separate
   from those involving a single Unicode version or Version 3.2 in
   particular, so they have been separated into this section and
   Section 3.

2.1. User Conceptions, Local Character Sets, and Input issues

   The labels of the DNS are just strings of characters that are not
   inherently tied to a particular language. As mentioned briefly in
   the Introduction, DNS labels that could not lexically be words in any
   language are possible and indeed common. There appears to be no
   reason to impose protocol restrictions on IDNs that would restrict
   them more than all-ASCII hostname labels have been restricted. For
   that reason, even describing DNS labels or strings of them as "names"
   is something of a misnomer, one that has probably added to user
   confusion about what to expect.

   Ordinarily, people use "words" when they think of things and wish
   others to think of them too, for example, "orange", "tree",
   "restaurant" or "Acme Inc". Words are normally in a specific
   language, such as English or Swedish. The character-string labels

supported by the DNS are, as suggested above, not inherently "words".
While it is useful, especially for mnemonic value or to identify
objects, for actual words to be used as DNS labels, other constraints
on the DNS make it impossible to guarantee that it will be possible
to represent every word in every language as a DNS label,
internationalized or not.

When writing or typing the label (or word), a script must be selected
and a charset must be picked for use with that script. The choice of
charset is typically not under the control of the user on a per-word
or per-document basis, but may depend on local input devices,
keyboard or terminal drivers, or other decisions made by operating
system or even hardware designers and implementers.

If that charset, or the local charset being used by the relevant
operating system or application software, is not Unicode, a further
conversion must be performed to produce Unicode. How often this is
an issue depends on estimates of how widely Unicode is deployed as
the native character set for hardware, operating systems, and
applications. Those estimates differ widely, but it should be noted
that, among other difficulties:

o ISO 8859 versions [ISO.8859.2003] and even national variations of
   ISO 646 [ISO.646.1991], are still widely used in parts of Europe;

o code-table switching methods, typically based on the techniques of
   ISO 2022 [ISO.2022.1986] are still in general use in many parts of
   the world, especially in Japan with Shift-JIS and its variations;
   and

o computing, systems, and communications in China tend to use one or
   more of the national "GB" standards rather than native Unicode.

Additionally, not all charsets define their characters in the same
way and not all preexisting coding systems were incorporated into
Unicode without changes. Sometimes local distinctions were made that
Unicode does not make or vice versa. Consequently, conversion from
other systems to Unicode may potentially lose information.

The Unicode string that results from this processing -- processing
that is trivial in a Unicode-native system but that may be
significant in others -- is then used as input to IDNA.

2.2. Examples of Issues

   While much of the discussion below is stated in terms of Unicode
   codings and associated rules, the IAB believes that some of the
   issues are actually not about the Unicode character set per se, but
   about how distributed matching systems operate in reality, and about
   what implications the distributed delayed search for stored data that
   characterizes the DNS has on the mapping algorithms.

2.2.1. Language-Specific Character Matching

   There are similar words that can be expressed in multiple languages.
   Consider, for example, the name Torbjorn in Norwegian and Swedish.
   In Norwegian it is spelled with the character U+00F8 (LATIN SMALL
   LETTER O WITH STROKE) in the second syllable, while in Swedish it is
   spelled with U+00F6 (LATIN SMALL LETTER O WITH DIAERESIS). Those
   characters are not treated as equivalent according to the Unicode
   Standard and its Annexes while most people speaking Swedish, Danish,
   or Norwegian probably think they are equivalent.

   It is neither possible nor desirable to make these characters
   equivalent on a global basis. To do so would, for this example,
   rationalize the situation in Sweden while causing considerable
   confusion in Germany because the U+00F8 character is never used in
   the German language. But the "variant" model introduced in [RFC3743]
   and [RFC4290] can be used by a registry to prevent the worst
   consequence of the possible confusion, by ensuring either that both
   names are registered to the same party in a given domain or that one
   of them is completely prohibited.

2.2.2. Multiple Scripts

   There are languages in the world that can be expressed using multiple
   scripts. For example, some Eastern European and Central Asian
   languages can be expressed in either Cyrillic or Latin (see
   Section 1.5.2) characters, or some African and Southeast Asian
   languages can be expressed in either Arabic or Latin characters. A
   few languages can even be written in three different scripts. In
   other cases, the language is typically written in a combination of
   scripts (e.g., Kanji, Kana, and Romaji for Japanese; Hangul and Hanji
   for Korean). Because of this, the same word, in the same language,
   can be expressed in different ways. For some languages, only a
   single script is normally used to write a single word; for others,
   mixed scripts are required; and, for still others, special
   circumstances may dictate mixing scripts in labels although that is
   not normally done for "words". For IDN purposes, these variations
   make the definition of "script" extremely sensitive, especially since
   ICANN is now recommending that it be used as the primary basis for

registry policies. However essential it may be to prohibit mixed-
script labels, additional policy nuance is required for "languages
with established orthographies and conventions that require the
commingled use of multiple scripts".

2.2.3. Normalization and Character Mappings

   Unicode contains several different models for representing
   characters. The Chinese (Han)-derived characters of the "CJK"
   (Chinese, Japanese, and Korean) languages are "unified", i.e.,
   characters with common derivation and similar appearances are
   assigned to the same code point. European characters derived from a
   Greek-Latin base are separated into separate code blocks for Latin,
   Greek, and Cyrillic even when individual characters are identical in
   both form and semantics. Separate code points based on font
   differences alone are generally prohibited, but a large number of
   characters for "mathematical" use have been assigned separate code
   points even though they differ from base ASCII characters only by
   font attributes such as "script", "bold", or "italic". Some
   characters that often appear together are treated as typographical
   digraphs with specific code points assigned to the combination,
   others require that the two-character sequences be used, and still
   others are available in both forms. Some Roman-derived letters that
   were developed as decorated variations on the basic Latin letter
   collection (e.g., by addition of diacritical marks) are assigned code
   points as individual characters, others must be built up as two (or
   more) character sequences using "combining characters".

   Many of these differences result from the desire to maintain backward
   compatibility while the standard evolved historically, and are hence
   understandable. However, the DNS requires precise knowledge of which
   codes and code sequences represent the same character and which ones
   do not. Limiting the potential difficulties with confusable
   characters (see Section 2.2.6) requires even more knowledge of which
   characters might look alike in some fonts but not in others. These
   variations make it difficult or impossible to apply a single set of
   rules to all of Unicode and, in doing so, satisfy everyone and their
   perceived needs. Instead, more or less complex mapping tables,
   defined on a character-by-character basis, are required to
   "normalize" different representations of the same character to a
   single form so that matching is possible.

   Unless normalization rules, such as those that underlie Nameprep, are
   applied, characters that are essentially identical will not match in
   the DNS, creating many opportunities for problems. The most common
   of these problems is that, due to the processing applied (and
   discussed above) before a word is represented as a Unicode string, a
   single word can end up being expressed as several different Unicode

strings. Even if normalization rules are applied, some strings that
are considered identical by users will not compare equal. That
problem is discussed in more detail elsewhere in this document,
particularly in Section 3.2.1.

IDNA attempts to compensate for these problems by using a
normalization algorithm defined by the Unicode Consortium. This
algorithm can change a sequence of one or more Unicode characters to
another set of characters. One example is that the base character
U+0061 (LATIN SMALL LETTER A) followed by U+0308 (COMBINING
DIAERESIS) is changed to the single Unicode character U+00E4 (LATIN
SMALL LETTER A WITH DIAERESIS).

This Unicode normalization process accounts only for simple character
equivalences, not equivalences that are language or script dependent.
For example, as mentioned above, the characters U+00F8 (LATIN SMALL
LETTER O WITH STROKE) and U+00F6 (LATIN SMALL LETTER O WITH
DIAERESIS) are considered to match in Swedish (and some other
languages), but not for all languages that use either of the
characters. Having these characters be treated as equivalent in some
contexts and not in others requires decisions and mechanisms that, in
turn, depend much more on context than either IDNA or the Unicode
character-based normalization tables can provide.

Additional complications occur if the sequences are more complicated
or if an attacker is making a deliberate effort to confuse the
normalization process. For example, if the sequence U+0069 U+0307
(LATIN SMALL LETTER I followed by COMBINING DOT ABOVE) appears, the
Unicode Normalization Method known as NFKC maps it into U+00EF (LATIN
SMALL LETTER I WITH DIAERESIS), which is what one would predict. But
consider U+0131 U+0308 (LATIN SMALL LETTER DOTLESS I and COMBINING
DIAERESIS): is that the same character? Is U+0131 U+0307 U+0307
(dotless i and two combining dot-above characters) equivalent to
U+00EF or U+0069, or neither? NFKC does not appear to tell us, nor
does the definition of U+0307 appear to tell us what happens when it
is combined with other "symbol above" arrangements (unlike some of
the "accent above" combining characters, which more or less specify
kerning). Similar issues arise when U+00EF is combined with various
dot-above combining characters. Each of these questions provides
some opportunities for spoofing if different display implementations
interpret the rules in different ways.

If we leave Latin scripts and examine those based on Chinese
characters, we see there is also an absence of specific, lexigraphic,
rules for transformations between Traditional and Simplified Chinese.
Even if there were such rules, unification of Japanese and Korean

characters with Chinese ones would make it impossible to normalize
Traditional Chinese into Simplified Chinese ones without causing
problems in Japanese and Korean use of the same characters.

More generally, while some mappings, such as those between
precomposed Latin script characters and the equivalent multiple code
point composed character sequences, depend only on the characters
themselves, in many or most cases, such as the case with Swedish
above, the mapping is language or culturally dependent. There have
been discussions as to whether different canonicalization rules (in
addition to or instead of Unicode normalization) should be, or could
be, applied differently to different languages or scripts. The fact
that most scripts included in Unicode have been initially
incorporated by copying an existing standard more or less intact has
impact on the optimization of these algorithms and on forward
compatibility. Even if the language is known and language-specific
rules can be defined, dependencies on the language do not disappear.
Canonicalization operations are not possible unless they either
depend only on short sequences of text or have significant context
available that is not obvious from the text itself. DNS lookups and
many other operations do not have a way to capture and utilize the
language or other information that would be needed to provide that
context.

These variations in languages and in user perceptions of characters
make it difficult or impossible to provide uniform algorithms for
matching Unicode strings in a way that no end users are ever
surprised by the result. For closely-related scripts or characters,
surprises may even be frequent. However, because uniform algorithms
are required for mappings that are applied when names are looked up
in the DNS, the rules that are chosen will always represent an
approximation that will be more or less successful in minimizing
those user surprises. The current Nameprep and Stringprep algorithms
use mapping tables to "normalize" different representations of the
same text to a single form so that matching is possible.

More details on the creation of the normalization algorithms can be
found in the Unicode Specification and the associated Technical
Reports [UTR] and Annexes. Technical Report #36 [UTR36] and [UTR39]
are specifically related to the IDN discussion.

2.2.4. URLs in Printed Form

   URLs and other identifiers appear, not only in electronic forms from
   which they can (at least in principle) be accurately copied and
   "pasted" but in printed forms from which the user must transcribe
   them into the computer system. This is often known as the "side-of-
   the-bus problem" because a particularly problematic version of it

requires that the user be able to observe and accurately remember a
URL that is quickly glimpsed in a transient form -- a billboard seen
while driving, a sign on the side of a passing vehicle, a television
advertisement that is not frequently repeated or on-screen for a long
time, and so on.

The difficulty, in short, is that two Unicode strings that are
actually different might look exactly the same, especially when there
is no time to study them. This is because, for example, some glyphs
in Cyrillic, Greek, and Latin do look the same, but have been
assigned different code points in Unicode. Worse, one needs to be
reasonably familiar with a script and how it is used to understand
how much characters can reasonably vary as the result of artistic
fonts and typography. For example, there are a few fonts for Latin
characters that are sufficiently highly ornamented that an observer
might easily confuse some of the characters with characters in Thai
script. Uppercase ITC Blackadder (a registered trademark of
International Typeface Corporation) and Curlz MT are two fairly
obvious examples; these fonts use loops at the end of serifs,
creating a resemblance to Thai (in some fonts) for some characters.

2.2.5. Bidirectional Text

Some scripts (and because of that some words in some languages) are
written not left to right, but right to left. And, to complicate
things, one might have something written in Arabic script right to
left that includes some characters that are read from left to right,
such as European-style digits. This implies that some texts might
have a mixed left-to-right AND right-to-left order (even though in
most implementations, and in IDNA, all texts have a major direction,
with the other as an exception).

IDNA permits the inclusion of European digits in a label that is
otherwise a sequence of right-to-left characters, but prohibits most
other mixed-directional (or bidirectional) strings. This prohibition
can cause other problems such as the rejection of some otherwise
linguistically and culturally sensible strings. As Unicode and
conventions for handling so-called bidirectional ("BIDI") strings
evolve, the prohibition in IDNA should be reviewed and reevaluated.

2.2.6. Confusable Character Issues

Similar-looking characters in identifiers can cause actual problems
on the Internet since they can result, deliberately or accidentally,
in people being directed to the wrong host or mailbox by believing
that they are typing, or clicking on, intended characters that are
different from those that actually appear in the domain name or
reference. See Section 4.1.3 for further discussion of this issue.

IDNs complicate these issues, not only by providing many additional
characters that look sufficiently alike to be potentially confused,
but also by raising new policy questions. For example, if a language
can be written in two different scripts, is a label constructed from
a word written in one script equivalent to a label constructed from
the same word written in the other script? Is the answer the same
for words in two different languages that translate into each other?

It is now generally understood that, in addition to the collision
problems of possibly equivalent words and hence labels, it is
possible to utilize characters that look alike -- "confusable"
characters -- to spoof names in order to mislead or defraud users.
That issue, driven by particular attacks such as those known as
"phishing", has introduced stronger requirements for registry efforts
to prevent problems than were previously generally recognized as
important.

One commonly-proposed approach is to have a registry establish
restrictions on the characters, and combinations of characters, it
will permit to be included in a string to be registered as a label.
Taking the Swedish top-level domain, .SE, as an example, a rule might
be adopted that the registry "only accepts registrations in Swedish,
using Latin script, and because of this, Unicode characters Latin-a,
-b, -c,...". But, because there is not a 1:1 mapping between country
and language, even a Country Code Top Level Domain (ccTLD) like .SE
might have to accept registrations in other languages. For example,
there may be a requirement for Finnish (the second most-used language
in Sweden). What rules and code points are then defined for Finnish?
Does it have special mappings that collide with those that are
defined for Swedish? And what does one do in countries that use more
than one script? (Finnish and Swedish use the same script.) In all
cases, the dispute will ultimately be about whether two strings are
the same (or confusingly similar) or not. That, in turn, will
generate a discussion of how one defines "what is the same" and "what
is similar enough to be a problem".

Another example arose recently that further illustrates the problem.
If one were to use Cyrillic characters to represent the country code
for Russia in a localized equivalent to the ccTLD label, the
characters themselves would be indistinguishable from the Latin
characters "P" and "Y" (in either lower- or uppercase) in most fonts.
We presume this might cause some consternation in Paraguay.

These difficulties can never be completely eliminated by algorithmic
means. Some of the problem can be addressed by appropriate tuning of
the protocols and their tables, other parts by registry actions to
reduce confusion and conflicts, and still other parts can be

addressed by careful design of user interfaces in application
programs. But, ultimately, some responsibility to avoid being
tricked or harmfully confused will rest with the user.

Another registry technique that has been extensively explored
involves looking at confusable characters and confusion between
complete labels, restricting the labels that can be registered based
on relationships to what is registered already. Registries that
adopt this approach might establish special mapping rules such as:

1. If you register something with code point A, domain names with B
    instead of A will be blocked from registration by others (where B
    is a character at a separate code point that has a confusingly
    similar appearance to A).

2. If you register something with code point A, you also get domain
    name with B instead of A.

These approaches are discussed in more detail for "CJK" characters in
RFC 3743 [RFC3743] and more generally in RFC 4290 [RFC4290].

2.2.7. The IESG Statement and IDNA issues

The issues above, at least as they were understood at the time,
provided the background for the IESG statement included in
Section 1.6.1 (which, in turn, was part of the basis for the initial
ICANN Guidelines) that a registry should have a policy about the
scripts, languages, code points and text directions for which
registrations will be accepted. While "accept all" might be an
acceptable policy, it implies there is also a dispute resolution
process that takes the problems listed above into account. This
process must be designed for dealing with all types of potential
disputes. For example, issues might arise between registrant and
registry over a decision by the registry on collisions with already
registered domain names and between registrant and trademark holder
(that a domain name infringes on a trademark). In both cases, the
parties disagreeing have different views on whether two strings are
"equivalent" or not. They may believe that a string that is not
allowed to be registered is actually different from one that is
already registered. Or they might believe that two strings are the
same, even though the rules adopted by the registry to prevent
confusion define them as two different domain names.

3. Migrating to New Versions of Unicode

3.1. Versions of Unicode

   While opinions differ about how important the issues are in practice,
   the use of Unicode and its supporting tables for IDNA appears to be
   far more sensitive to subtle changes than it is in typical Unicode
   applications. This may be, at least in part, because many other
   applications are internally sensitive only to the appearance of
   characters and not to their representation. Or those applications
   may be able to take effective advantage of script, language, or
   character class identification. The working group that developed
   IDNA concluded that attempting to encode any ancillary character
   information into the DNS label would be impractical and unwise, and
   the IAB, based in part on the comments in the ad hoc committee, saw
   no reason to review that decision.

   The Unicode Consortium has sometimes used the likelihood of a
   combination of characters actually appearing in a natural language as
   a criterion for the safety of a possible change. However, as
   discussed above, DNS names are often fabrications -- abbreviations,
   strings deliberately formed to be unusual, members of a series
   sequenced by numbers or other characters, and so on. Consequently, a
   criterion that considers a change to be safe if it would not be
   visible in properly-constructed running text is not helpful for DNS
   purposes: a change that would be safe under that criterion could
   still be quite problematic for the DNS.

   This sensitivity to changes has made it quite difficult to migrate
   IDNA from one version of Unicode to the next if any changes are made
   that are not strictly additive. A change in a code point assignment
   or definition may be extremely disruptive if a DNS label has been
   defined using the earlier form and any of its previous components has
   been moved from one table position or normalization rule to another.
   Unicode normalization tables, tables of scripts or languages and
   characters that belong to them, and even tables of confusable
   characters as an adjunct to security recommendations may be very
   helpful in designing registry restrictions on registrations and
   applications provisions for avoiding or identifying suspicious names.
   Ironically, they also extend the sensitivity of IDNA and its
   implementations to all forms of change between one version of Unicode
   and the next. Consequently, they make Unicode version migration more
   difficult.

   An example of the type of change that appears to be just a small
   correction from one perspective but may be problematic from another
   was the correction to the normalization definition in 2004
   [Unicode-PR29]. Community input suggested that the change would

   cause problems for Stringprep, but the Unicode Technical Committee
   decided, on balance, that the change was worthwhile. Because of
   difficulties with consistency, some deployed implementations have
   decided to adopt the change and others have not, leading to subtle
   incompatibilities.

   This situation leads to a dilemma. On the one hand, it is completely
   unacceptable to freeze IDNA at a Unicode version level that excludes
   more recently-defined characters and scripts that are important to
   those who use them. On the other hand, it is equally unacceptable to
   migrate from one version of Unicode to the next if such migration
   might invalidate an existing registered DNS name or some of its
   registered properties or might make the string or representation of
   that name ambiguous. If IDNA is to be modified to accommodate new
   versions of Unicode, the IETF will need to work with the Unicode
   Consortium and other bodies to find an appropriate balance in this
   area, but progress will be possible only if all relevant parties are
   able to fairly consider and discuss possible decisions that may be
   very difficult and unpalatable.

   It would also prove useful if, during the course of that dialog, the
   need for Unicode Consortium concern with security issues in
   applications of the Unicode character set could be clarified. It
   would be unfortunate from almost every perspective considered here,
   if such matters slowed the inclusion of as yet unencoded scripts.

3.2. Version Changes and Normalization Issues

3.2.1. Unnormalized Combining Sequences

   One of the advantages of the Unicode model of combining characters,
   as with previous systems that use character overstriking to
   accomplish similar purposes, is that it is possible to use sequences
   of code points to generate characters that are not explicitly
   provided for in the character set. However, unless sequences that
   are not explicitly provided for are prohibited by some mechanism
   (such as the normalization tables), such combining sequences can
   permit two related dangers.

   o The first is another risk of character confusion, especially if
      the relationship of the combining character with characters it
      combines with are not precisely defined or unexpected combinations
      of combining characters are used. That issue is discussed in more
      detail, with an example, in Section 2.2.3.

   o These same issues also inherently impact the stability of the
      normalization tables. Suppose that, somewhere in the world, there
      is a character that looks like a Roman-derived lowercase "i", but

with three (not one or two) dots above it. And suppose that the
users of that character agree to represent it by combining a
traditional "i" (U+0069) with a combining diaeresis (U+0308). So
far, no problem. But, later, a broader need for this character is
discovered and it is coded into Unicode either as a single
precomposed character or, more likely under existing rules, by
introducing a three-dot-above combining character. In either
case, that version of Unicode should include a rule in NFKC that
maps the "i"-plus-diaeresis sequence into the new, approved, one.
If one does not do so, then there is arguably a normalization that
should occur that does not. If one does so, then strings that
were valid and normalized (although unanticipated) under the
previous versions of Unicode become unnormalized under the new
version. That, in turn, would impact IDNA comparisons because,
effectively, it would introduce a change in the matching rules.

It would be useful to consider rules that would avoid or minimize
these problems with the understanding that, for reasons given
elsewhere, simply minimizing it may not be good enough for IDNA. One
partial solution might be to ban any combination of a base character
and a combining character that does not appear in a hypothetical
"anticipated combinations" table from being used in a domain name
label. The next subsection discusses a more radical, if impractical,
view of the problem and its solutions.

3.2.2. Combining Characters and Character Components

For several reasons, including those discussed above, one thing that
increases IDNA complexity and the need for normalization is that
combining characters are permitted. Without them, complexity might
be reduced enough to permit easier transitions to new versions. The
community should consider the impact of entirely prohibiting
combining characters from IDNs. While it is almost certainly
unfeasible to introduce this change into Unicode as it is now defined
and doing so would be extremely disruptive even if it were feasible,
the thought experiment can be helpful in understanding both the
issues and the implications of the paths not taken. For example, one
consequence of this, of course, is that each new language or script,
and several existing ones, would require that all of its characters
have Unicode assignments to specific, precomposed, code points.

Note that this is not currently permitted within Unicode for Latin
scripts. For non-Latin scripts, some such code points have been
defined. The decisions that govern the assignment of such code
points are managed entirely within the Unicode Consortium. Were the
IETF to choose to reduce IDNA complexity by excluding combining
characters, no doubt there would be additional input to the Unicode
Consortium from users and proponents of scripts that precomposed

characters be required. The IAB and the IETF should examine whether
it is appropriate to press the Unicode Consortium to revise these
policies or otherwise to recommend actions that would reduce the need
for normalization and the related complexities. However, we have
been told that the Technical Committee does not believe it is
reasonable or feasible to add all possible precomposed characters to
Unicode. If Unicode cannot be modified to contain the precomposed
characters necessary to support existing languages and scripts, much
less new ones, this option for IDN restrictions will not be feasible.

3.2.3. When does normalization occur?

In many Unicode applications, the preferred solution is to pick a
style of normalization and require that all text that is stored or
transmitted be normalized to that form. (This is the approach taken
in ongoing work in the IETF on a standard Unicode text form
[net-utf8]). IDNA does not impose this requirement. Text is
normalized and case-reduced at registration time, and only the
normalized version is placed in the DNS. However, there is no
requirement that applications show only the native (and lower-case
where appropriate) characters associated with the normalized form in
discussions or references such as URLs. If conventions used for
all-ASCII DNS labels are to be extended to internationalized forms,
such a requirement would be unreasonable, since it would prohibit the
use of mixed-case references for clarity or market identification.
It might even be culturally inappropriate. However, without that
restriction, the comparison that will ultimately be made in the DNS
will be between strings normalized at different times and under
different versions of Unicode. The assertion that a string in
normalized form under one version of Unicode will still be in
normalized form under all future versions is not sufficient.
Normalization at different times also requires that a given source
string always normalizes to the same target string, regardless of the
version under which it is normalized. That criterion is much more
difficult to fulfill. The discussion above suggests that it may even
be impossible.

Ignoring these issues with combining characters entirely, as IDNA
effectively does today, may leave us "stuck" at Unicode 3.2, leading
either to incompatibility differences in applications that otherwise
use a modern version of Unicode (while IDN remains at Unicode 3.2) or
to painful transitions to new versions. If decisions are made
quickly, it may still be possible to make a one-time version upgrade
to Version 4.1 or Version 5 of Unicode. However, unless we can
impose sufficient global restrictions to permit smooth transitions,
upgrading to versions beyond that one are likely to be painful (e.g.,
potentially requiring changing strings already in the DNS or even a
new Punycode prefix) or impossible.

4. Framework for Next Steps in IDN Development

4.1. Issues within the Scope of the IETF

4.1.1. Review of IDNA

   The IETF should consider reviewing RFCs 3454, 3490, 3491, and/or
   3492, and update, replace, or supplement them to meet the criteria of
   this paragraph (one or more of them may prove impractical after
   further study). Any new versions or additional specifications should
   be adapted to the version of Unicode that is current when they are
   created. Ideally, they should specify a path for adapting to future
   versions of Unicode (some suggestions below may facilitate this).
   The IETF should also consider whether there are significant
   advantages to mapping some groups of characters, such as code points
   assigned to font variations, into others or whether clarity and
   comprehensibility for the user would be better served by simply
   prohibiting those characters. More generally, it appears that it
   would be worthwhile for the IETF to review whether the Unicode
   normalization rules now invoked by the Stringprep profile in Nameprep
   are optimal for the DNS or whether more restrictive rules, or an even
   more restrictive set of permitted character combinations, would
   provide better support for DNS internationalization.

   The IAB has concluded that there is a consensus within the broader
   community that lists of code points should be specified by the use of
   an inclusion-based mechanism (i.e., identifying the characters that
   are permitted), rather than by excluding a small number of characters
   from the total Unicode set as Stringprep and Nameprep do today. That
   conclusion should be reviewed by the IETF community and action taken
   as appropriate.

   We suggest that the individuals doing the review of the code points
   should work as a specialized design team. To the extent possible,
   that work should be done jointly by people with experience from the
   IETF and deep knowledge of the constraints of the DNS and application
   design, participants from the Unicode Consortium, and other people
   necessary to be able to reach a generally-accepted result. Because
   any work along these lines would be modifications and updates to
   standards-track documents, final review and approval of any proposals
   would necessarily follow normal IETF processes.

   It is worth noting that sufficiently extreme changes to IDNA would
   require a new Punycode prefix, probably with long-term support for
   both the old prefix and the new one in both registration arrangements
   and applications. An alternative, which is almost certainly
   impractical, would be some sort of "flag day", i.e., a date on which
   the old rules are simultaneously abandoned by everyone and the new

ones adopted. However, preliminary analysis indicates that few, if
any, of the changes recommended for consideration elsewhere in this
document would require this type of version change. For example,
suppose additional restrictions, such as those implied above, are
imposed on what can be registered. Those restrictions might require
policy decisions about how labels are to be disposed of if they
conformed to the earlier rules but not to the new ones. But they
would not inherently require changes in the protocol or prefix.

4.1.2. Non-DNS and Above-DNS Internationalization Approaches

The IETF should once again examine the extent to which it is
appropriate to try to solve internationalization problems via the DNS
and what place the many varieties of so-called "keyword systems" or
other Internet navigational techniques might have. Those techniques
can be designed to impose fewer constraints, or at least different
constraints, than IDNA and the DNS. As discussed elsewhere in this
document, IDNA cannot support information about scripts, languages,
or Unicode versions on lookup. As a consequence of the nature of DNS
lookups, characters and labels either match or do not match; a near-
match is simply not a possible concept in the DNS. By contrast,
observation of near-matching is common in human communication and in
matching operations performed by people, especially when they have a
particular script or language context in mind. The DNS is further
constrained by a fairly rigid internal aliasing system (via CNAME and
DNAME resource records), while some applications of international
naming may require more flexibility. Finally, the rigid hierarchy of
the DNS --and the tendency in practice for it to become flat at
levels nearest the root-- and the need for names to be unique are
more suitable for some purposes than others and may not be a good
match for some purposes for which people wish to use IDNs. Each of
these constraints can be relaxed or changed by one or more systems
that would provide alternatives to direct use of the DNS by users.
Some of the issues involved are discussed further in Section 5.3 and
various ideas have been discussed in detail in the IETF or IRTF.
Many of those ideas have even been described in Internet Drafts or
other documents. As experience with IDNs and with expectations for
them accumulates, it will probably become appropriate for the IETF or
IRTF to revisit the underlying questions and possibilities.

4.1.3. Security Issues, Certificates, etc.

Some characters look like others, often as the result of common
origins. The problem with these "confusable" characters, often
incorrectly called homographs, has always existed when characters are
presented to humans who interpret what is displayed and then make
decisions based on what is seen. This is not a problem that exists
only when working with internationalized domain names, but they make

the problem worse. The result of a survey that would explain what
the problems are might be interesting. Many of these issues are
mentioned in Unicode Technical Report #36 [UTR36].

In this and other issues associated with IDNs, precise use of
terminology is important lest even more confusion result. The
definition of the term 'homograph' that normally appears in
dictionaries and linguistic texts states that homographs are
different words that are spelled identically (for example, the
adjective 'brief' meaning short, the noun 'brief' meaning a document,
and the verb 'brief' meaning to inform). By definition, letters in
two different alphabets are not the same, regardless of similarities
in appearance. This means that sequences of letters from two
different scripts that appear to be identical on a computer display
cannot be homographs in the accepted sense, even if they are both
words in the dictionary of some language. Assuming that there is a
language written with Cyrillic script in which "cap" is a word,
regardless of what it might mean, it is not a homograph of the
Latin-script English word "cap".

When the security implications of visually confusable characters were
brought to the forefront in 2005, the term homograph was used to
designate any instance of graphic similarity, even when comparing
individual characters. This usage is not only incorrect, but risks
introducing even more confusion and hence should be avoided. The
current preferred terminology is to describe these similar-looking
characters as "confusable characters" or even "confusables".

Many people have suggested that confusable characters are a problem
that must be addressed, at least in part, directly in the user
interfaces of application software. While it should almost certainly
be part of a complete solution, that approach creates it own set of
difficulties. For example, a user switching between systems, or even
between applications on the same system, may be surprised by
different types of behavior and different levels of protection. In
addition, it is unclear how a secure setup for the end user should be
designed. Today, in the web browser, a padlock is a traditional way
of describing some level of security for the end user. Is this
binary signaling enough? Should there be any connection between a
risk for a displayed string including confusable characters and the
padlock or similar signaling to the user?

Many web browsers have adopted a convention, based on a "whitelist"
or similar technique, of restricting the display of native characters
to subdomains of top-level domains that are deemed to have safe
practices for the registration of potentially confusable labels.
IDNs in other domains are displayed as Punycode. These techniques
may not be sufficiently sensitive to differences in policies among

top-level domains and their subdomains and so, while they are clearly
helpful, they may not be adequate. Are other methods of dealing with
confusable characters possible? Would other methods of identifying
and listing policies about avoiding confusing registrations be
feasible and helpful?

It would be interesting to see a more coordinated effort in
establishing guidelines for user interfaces. If nothing else, the
current whitelists are browser specific and both can, and do, differ
between implementations.

4.1.4. Protocol Changes and Policy Implications

Some potential protocol or table changes raise important policy
issues about what to do with existing, registered, names. Should
such changes be needed, their impact must be carefully evaluated in
the IETF, ICANN, and possibly other forums. In particular, protocol
or policy changes that would not permit existing names to be
registered under the newer rules should be considered carefully,
balancing their importance against possible disruption and the issues
of invalidating older names against the importance of consistency as
seen by the user.

4.1.5. Non-US-ASCII in Local Part of Email Addresses

Work is going on in the IETF related to the local part of email
addresses. It should be noted that the local part of email addresses
has much different syntax and constraints than a domain name label,
so to directly apply IDNA on the local part is not possible.

4.1.6. Use of the Unicode Character Set in the IETF

Unicode and the closely-related ISO 10646 are the only coded
character sets that aspire to include all of the world's characters.
As such, they permit use of international characters without having
to identify particular character coding standards or tables. The
requirement for a single character set is particularly important for
use with the DNS since there is no place to put character set
identification. The decision to use Unicode as the base for IETF
protocols going forward is discussed in [RFC2277]. The IAB does not
see any reason to revisit the decision to use Unicode in IETF
protocols.

4.2. Issues That Fall within the Purview of ICANN

4.2.1. Dispute Resolution

   IDNs create new types of collisions between trademarks and domain
   names as well as collisions between domain names. These have impact
   on dispute resolution processes used by registries and otherwise. It
   is important that deployment of IDNs evolve in parallel with review
   and updating of ICANN or registry-specific dispute resolution
   processes.

4.2.2. Policy at Registries

   The IAB recommends that registries use an inclusion-based model when
   choosing what characters to allow at the time of registration. This
   list of characters is in turn to be a subset of what is allowed
   according to the updated IDNA standard. The IAB further recommends
   that registries develop their inclusion-based models in parallel with
   dispute resolution process at the registry itself.

   Most established policies for dealing with claimed or apparent
   confusion or conflicts of names are based on dispute resolution.
   Decisions about legitimate use or registration of one or more names
   are resolved at or after the time of registration on a case-by-case
   basis and using policies that are specific to the particular DNS zone
   or jurisdiction involved. These policies have generally not been
   extended below the level of the DNS that is directly controlled by
   the top-level registry.

   Because of the number of conflicts that can be generated by the
   larger number of available and confusable characters in Unicode, we
   recommend that registration-restriction and dispute resolution
   policies be developed to constrain registration of IDNs and zone
   administrators at all levels of the DNS tree. Of course, many of
   these policies will be less formal than others and there is no
   requirement for complete global consistency, but the arguments for
   reduction of confusable characters and other issues in TLDs should
   apply to all zones below that specific TLD.

   Consistency across all zones can obviously only be accomplished by
   changes to the protocols. Such changes should be considered by the
   IETF if particular restrictions are identified that are important and
   consistent enough to be applied globally.

   Some potential protocol changes or changes to character-mapping
   tables might, if adopted, have profound registry policy implications.
   See Section 4.1.4.

4.2.3. IDNs at the Top Level of the DNS

   The IAB has concluded that there is not one issue with IDNs at the
   top level of the DNS (IDN TLDs) but at least three very separate
   ones:

   o If IDNs are to be entered in the root zone, decisions must first
      be made about how these TLDs are to be named and delegated. These
      decisions fall within the traditional IANA scope and are ICANN
      issues today.

   o There has been discussion of permitting some or all existing TLDs
      to be referenced by multiple labels, with those labels presumably
      representing some understanding of the "name" of the TLD in
      different languages. If actual aliases of this type are desired
      for existing domains, the IETF may need to consider whether the
      use of DNAME records in the root is appropriate to meet that need,
      what constraints, if any, are needed, whether alternate
      approaches, such as those of [RFC4185], are appropriate or whether
      further alternatives should be investigated. But, to the extent
      to which aliases are considered desirable and feasible, decisions
      presumably must be made as to which, if any, root IDN labels
      should be associated with DNAME records and which ones should be
      handled by normal delegation records or other mechanisms. That
      decision is one of DNS root-level namespace policy and hence falls
      to ICANN although we would expect ICANN to pay careful attention
      to any technical, operational, or security recommendations that
      may be produced by other bodies.

   o Finally, if IDN labels are to be placed in the root zone, there
      are issues associated with how they are to be encoded and
      deployed. This area may have implications for work that has been
      done, or should be done, in the IETF.

5. Specific Recommendations for Next Steps

   Consistent with the framework described above, the IAB offers these
   recommendations as steps for further consideration in the identified
   groups.

5.1. Reduction of Permitted Character List

   Generalize from the original "hostname" rules to non-ASCII
   characters, permitting as few characters as possible to do that job.
   This would involve a restrictive model for characters permitted in
   IDN labels, thus contrasting with the approach used to develop the
   original IDNA/Nameprep tables. That approach was to include all
   Unicode characters that there was not a clear reason to exclude.

The specific recommendation here is to specify such internationalized
hostnames. Such an activity would fall to the IETF, although the
task of developing the appropriate list of permitted characters will
require effort both in the IETF and elsewhere. The effort should be
as linguistically and culturally sensitive as possible, but smooth
and effective operation of the DNS, including minimizing of
complexity, should be primary goals. The following should be
considered as possible mechanisms for achieving an appropriate
minimum number of characters.

5.1.1. Elimination of All Non-Language Characters

Unicode characters that are not needed to write words or numbers in
any of the world's languages should be eliminated from the list of
characters that are appropriate in DNS labels. In addition to such
characters as those used for box-drawing and sentence punctuation,
this should exclude punctuation for word structure and other
delimiters. While DNS labels may conveniently be used to express
words in many circumstances, the goal is not to express words (or
sentences or phrases), but to permit the creation of unambiguous
labels with good mnemonic value.

5.1.2. Elimination of Word-Separation Punctuation

The inclusion of the hyphen in the original hostname rules is a
historical artifact from an older, flat, namespace. The community
should consider whether it is appropriate to treat it as a simple
legacy property of ASCII names and not attempt to generalize it to
other scripts. We might, for example, not permit claimed equivalents
to the hyphen from other scripts to be used in IDNs. We might even
consider banning use of the hyphen itself in non-ASCII strings or,
less restrictively, strings that contained non-Latin characters.

5.2. Updating to New Versions of Unicode

As new scripts, to support new languages, continue to be added to
Unicode, it is important that IDNA track updates. If it does not do
so, but remains "stuck" at 3.2 or some single later version, it will
not be possible to include labels in the DNS that are derived from
words in languages that require characters that are available only in
later versions. Making those upgrades is difficult, and will
continue to be difficult, as long as new versions require, not just
addition of characters, but changes to canonicalization conventions,
normalization tables, or matching procedures (see Section 3.1).
Anything that can be done to lower complexity and simplify forward
transitions should be seriously considered.

5.3. Role and Uses of the DNS

   We wish to remind the community that there are boundaries to the
   appropriate uses of the DNS. It was designed and implemented to
   serve some specific purposes. There are additional things that it
   does well, other things that it does badly, and still other things it
   cannot do at all. No amount of protocol work on IDNs will solve
   problems with alternate spellings, near-matches, searching for
   appropriate names, and so on. Registration restrictions and
   carefully-designed user interfaces can be used to reduce the risk and
   pain of attempts to do some of these things gone wrong, as well as
   reducing the risks of various sort of deliberate bad behavior, but,
   beyond a certain point, use of the DNS simply because it is available
   becomes a bad tradeoff. The tradeoff may be particularly unfortunate
   when the use of IDNs does not actually solve the proposed problem.
   For example, internationalization of DNS names does not eliminate the
   ASCII protocol identifiers and structure of URIs [RFC3986] and even
   IRIs [RFC3987]. Hence, DNS internationalization itself, at any or
   all levels of the DNS tree, is not a sufficient response to the
   desire of populations to use the Internet entirely in their own
   languages and the characters associated with those languages.

   These issues are discussed at more length, and alternatives
   presented, in [RFC2825], [RFC3467], [INDNS], and [DNS-Choices].

5.4. Databases of Registered Names

   In addition to their presence in the DNS, IDNs introduce issues in
   other contexts in which domain names are used. In particular, the
   design and content of databases that bind registered names to
   information about the registrant (commonly described as "whois"
   databases) will require review and updating. For example, the whois
   protocol itself [RFC3912] has no standard capability for handling
   non-ASCII text: one cannot search consistently for, or report, either
   a DNS name or contact information that is not in ASCII characters.
   This may provide some additional impetus for a switch to IRIS
   [RFC3981] [RFC3982] but also raises a number of other questions about
   what information, and in what languages and scripts, should be
   included or permitted in such databases.

6. Security Considerations

   This document is simply a discussion of IDNs and IDNA issues; it
   raises no new security concerns. However, if some of its
   recommendations to reduce IDNA complexity, the number of available
   characters, and various approaches to constraining the use of
   confusable characters, are followed and prove successful, the risks
   of name spoofing and other problems may be reduced.

7. Acknowledgements

   The contributions to this report from members of the IAB-IDN ad hoc
   committee are gratefully acknowledged. Of course, not all of the
   members of that group endorse every comment and suggestion of this
   report. In particular, this report does not claim to reflect the
   views of the Unicode Consortium as a whole or those of particular
   participants in the work of that Consortium.

   The members of the ad hoc committee were: Rob Austein, Leslie Daigle,
   Tina Dam, Mark Davis, Patrik Faltstrom, Scott Hollenbeck, Cary Karp,
   John Klensin, Gervase Markham, David Meyer, Thomas Narten, Michael
   Suignard, Sam Weiler, Bert Wijnen, Kurt Zeilenga, and Lixia Zhang.

   Thanks are due to Tina Dam and others associated with the ICANN IDN
   Working Group for contributions of considerable specific text, to
   Marcos Sanz and Paul Hoffman for careful late-stage reading and
   extensive comments, and to Pete Resnick for many contributions and
   comments, both in conjunction with his former IAB service and
   subsequently. Olaf M. Kolkman took over IAB leadership for this
   document after Patrik Faltstrom and Pete Resnick stepped down in
   March 2006.

   Members of the IAB at the time of approval of this document were:
   Bernard Aboba, Loa Andersson, Brian Carpenter, Leslie Daigle, Patrik
   Faltstrom, Bob Hinden, Kurtis Lindqvist, David Meyer, Pekka Nikander,
   Eric Rescorla, Pete Resnick, Jonathan Rosenberg and Lixia Zhang.

8. References

8.1. Normative References

   [ISO10646]   International Organization for Standardization,
                       "Information Technology - Universal Multiple-
                       Octet Coded Character Set (UCS) - Part 1:
                       Architecture and Basic Multilingual Plane"",
                       ISO/IEC 10646-1:2000, October 2000.

   [RFC3454]   Hoffman, P. and M. Blanchet, "Preparation of
                       Internationalized Strings ("stringprep")",
                       RFC 3454, December 2002.

   [RFC3490]   Faltstrom, P., Hoffman, P., and A. Costello,
                       "Internationalizing Domain Names in Applications
                       (IDNA)", RFC 3490, March 2003.

   [RFC3491]   Hoffman, P. and M. Blanchet, "Nameprep: A
                           Stringprep Profile for Internationalized Domain
                           Names (IDN)", RFC 3491, March 2003.

   [RFC3492]   Costello, A., "Punycode: A Bootstring encoding of
                           Unicode for Internationalized Domain Names in
                           Applications (IDNA)", RFC 3492, March 2003.

   [Unicode32]   The Unicode Consortium, "The Unicode Standard,
                           Version 3.0", 2000.
                           (Reading, MA, Addison-Wesley, 2000. ISBN
                           0-201-61633-5). Version 3.2 consists of the
                           definition in that book as amended by the Unicode
                           Standard Annex #27: Unicode 3.1
                           (http://www.unicode.org/reports/tr27/) and by the
                           Unicode Standard Annex #28: Unicode 3.2
                           (http://www.unicode.org/reports/tr28/).

8.2. Informative References

   [DNS-Choices]   Faltstrom, P., "Design Choices When Expanding
                           DNS", Work in Progress, June 2005.

   [ICANNv1]   ICANN, "Guidelines for the Implementation of
                           Internationalized Domain Names, Version 1.0",
                           March 2003, <http://www.icann.org/general/
                           idn-guidelines-20jun03.htm>.

   [ICANNv2]   ICANN, "Guidelines for the Implementation of
                           Internationalized Domain Names, Version 2.0",
                           November 2005, <http://www.icann.org/general/
                           idn-guidelines-20sep05.htm>.

   [IESG-IDN]   Internet Engineering Steering Group (IESG), "IESG
                           Statement on IDN", IESG Statements IDN Statement,
                           February 2003, <http://www.ietf.org/IESG/
                           STATEMENTS/IDNstatement.txt>.

   [INDNS]   National Research Council, "Signposts in
                           Cyberspace: The Domain Name System and Internet
                           Navigation", National Academy Press ISBN 0309-
                           09640-5 (Book) 0309-54979-5 (PDF), 2005, <http://
                           www7.nationalacademies.org/cstb/pub_dns.html>.

   [ISO.2022.1986]   International Organization for Standardization,
                           "Information Processing: ISO 7-bit and 8-bit
                           coded character sets: Code extension techniques",
                           ISO Standard 2022, 1986.

   [ISO.646.1991]   International Organization for Standardization,
                           "Information technology - ISO 7-bit coded
                           character set for information interchange",
                           ISO Standard 646, 1991.

   [ISO.8859.2003]   International Organization for Standardization,
                           "Information processing - 8-bit single-byte coded
                           graphic character sets - Part 1: Latin alphabet
                           No. 1 (1998) - Part 2: Latin alphabet No. 2
                           (1999) - Part 3: Latin alphabet No. 3 (1999) -
                           Part 4: Latin alphabet No. 4 (1998) - Part 5:
                           Latin/Cyrillic alphabet (1999) - Part 6: Latin/
                           Arabic alphabet (1999) - Part 7: Latin/Greek
                           alphabet (2003) - Part 8: Latin/Hebrew alphabet
                           (1999) - Part 9: Latin alphabet No. 5 (1999) -
                           Part 10: Latin alphabet No. 6 (1998) - Part 11:
                           Latin/Thai alphabet (2001) - Part 13: Latin
                           alphabet No. 7 (1998) - Part 14: Latin alphabet
                           No. 8 (Celtic) (1998) - Part 15: Latin alphabet
                           No. 9 (1999) - Part 16: Part 16: Latin alphabet
                           No. 10 (2001)", ISO Standard 8859, 2003.

   [RFC2277]   Alvestrand, H., "IETF Policy on Character Sets
                           and Languages", BCP 18, RFC 2277, January 1998.

   [RFC2825]   IAB and L. Daigle, "A Tangled Web: Issues of
                           I18N, Domain Names, and the Other Internet
                           protocols", RFC 2825, May 2000.

   [RFC3066]   Alvestrand, H., "Tags for the Identification of
                           Languages", BCP 47, RFC 3066, January 2001.

   [RFC3467]   Klensin, J., "Role of the Domain Name System
                           (DNS)", RFC 3467, February 2003.

   [RFC3536]   Hoffman, P., "Terminology Used in
                           Internationalization in the IETF", RFC 3536,
                           May 2003.

   [RFC3743]   Konishi, K., Huang, K., Qian, H., and Y. Ko,
                           "Joint Engineering Team (JET) Guidelines for
                           Internationalized Domain Names (IDN) Registration
                           and Administration for Chinese, Japanese, and
                           Korean", RFC 3743, April 2004.

   [RFC3912]   Daigle, L., "WHOIS Protocol Specification",
                           RFC 3912, September 2004.

   [RFC3981]   Newton, A. and M. Sanz, "IRIS: The Internet
                         Registry Information Service (IRIS) Core
                         Protocol", RFC 3981, January 2005.

   [RFC3982]   Newton, A. and M. Sanz, "IRIS: A Domain Registry
                         (dreg) Type for the Internet Registry Information
                         Service (IRIS)", RFC 3982, January 2005.

   [RFC3986]   Berners-Lee, T., Fielding, R., and L. Masinter,
                         "Uniform Resource Identifier (URI): Generic
                         Syntax", STD 66, RFC 3986, January 2005.

   [RFC3987]   Duerst, M. and M. Suignard, "Internationalized
                         Resource Identifiers (IRIs)", RFC 3987,
                         January 2005.

   [RFC4185]   Klensin, J., "National and Local Characters for
                         DNS Top Level Domain (TLD) Names", RFC 4185,
                         October 2005.

   [RFC4290]   Klensin, J., "Suggested Practices for
                         Registration of Internationalized Domain Names
                         (IDN)", RFC 4290, December 2005.

   [RFC4645]   Ewell, D., "Initial Language Subtag Registry",
                         RFC 4645, September 2006.

   [RFC4646]   Phillips, A. and M. Davis, "Tags for Identifying
                         Languages", BCP 47, RFC 4646, September 2006.

   [UTR]   Unicode Consortium, "Unicode Technical Reports",
                         <http://www.unicode.org/reports/>.

   [UTR36]   Davis, M. and M. Suignard, "Unicode Technical
                         Report #36: Unicode Security Considerations",
                         November 2005, <http://www.unicode.org/draft/
                         reports/tr36/tr36.html>.

   [UTR39]   Davis, M. and M. Suignard, "Unicode Technical
                         Standard #39 (proposed): Unicode Security
                         Considerations", July 2005, <http://
                         www.unicode.org/draft/reports/tr39/tr39.html>.

   [Unicode-PR29]   The Unicode Consortium, "Public Review Issue #29:
                         Normalization Issue", Unicode PR 29,
                         February 2004.

   [Unicode10]   The Unicode Consortium, "The Unicode Standard,

                        Version 1.0", 1991.

   [W3C-Localization]   Ishida, R. and S. Miller, "Localization vs.
                        Internationalization", W3C International/
                        questions/qa-i18n.txt, December 2005.

   [net-utf8]   Klensin, J. and M. Padlipsky, "Unicode Format for
                        Network Interchange", Work in Progress,
                        April 2006.

Authors' Addresses

   John C Klensin
   1770 Massachusetts Ave, #322
   Cambridge, MA   02140
   USA

   Phone: +1 617 491 5735
   EMail: john-ietf@jck.com

   Patrik Faltstrom
   Cisco Systems

   EMail: paf@cisco.com

   Cary Karp
   Swedish Museum of Natural History
   Box 50007
   Stockholm   SE-10405
   Sweden

   Phone: +46 8 5195 4055
   EMail: ck@nrm.museum

   IAB

   EMail: iab@iab.org

Full Copyright Statement

   Copyright (C) The Internet Society (2006).

   This document is subject to the rights, licenses and restrictions
   contained in BCP 78, and except as set forth therein, the authors
   retain all their rights.

   This document and the information contained herein are provided on an
   "AS IS" basis and THE CONTRIBUTOR, THE ORGANIZATION HE/SHE REPRESENTS
   OR IS SPONSORED BY (IF ANY), THE INTERNET SOCIETY AND THE INTERNET
   ENGINEERING TASK FORCE DISCLAIM ALL WARRANTIES, EXPRESS OR IMPLIED,
   INCLUDING BUT NOT LIMITED TO ANY WARRANTY THAT THE USE OF THE
   INFORMATION HEREIN WILL NOT INFRINGE ANY RIGHTS OR ANY IMPLIED
   WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

Intellectual Property

   The IETF takes no position regarding the validity or scope of any
   Intellectual Property Rights or other rights that might be claimed to
   pertain to the implementation or use of the technology described in
   this document or the extent to which any license under such rights
   might or might not be available; nor does it represent that it has
   made any independent effort to identify any such rights. Information
   on the procedures with respect to rights in RFC documents can be
   found in BCP 78 and BCP 79.

   Copies of IPR disclosures made to the IETF Secretariat and any
   assurances of licenses to be made available, or the result of an
   attempt made to obtain a general license or permission for the use of
   such proprietary rights by implementers or users of this
   specification can be obtained from the IETF on-line IPR repository at
   http://www.ietf.org/ipr.

   The IETF invites any interested party to bring to its attention any
   copyrights, patents or patent applications, or other proprietary
   rights that may cover technology that may be required to implement
   this standard. Please address the information to the IETF at
   ietf-ipr@ietf.org.

Acknowledgement

   Funding for the RFC Editor function is provided by the IETF
   Administrative Support Activity (IASA).