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Internationalization for the NFSv4 Protocols
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Abstract

This document describes the handling of internationalization for all NFSv4 protocols, including NFSv4.0, NFSv4.1, NFSv4.2 and extensions thereof, and future minor versions.

It updates [RFC7530](#) (formally) and [RFC5661](#) (substantively).

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[1.](#) Introduction

Internationalization is a complex topic with its own set of terminology (see [\[RFC6365\]](#)). The topic is made more complex for the NFSv4 protocols by the tangled history described in [Section 3](#). This document is based on the actual behavior of NFSv4 client and server implementations (for all existing minor versions) and is intended to serve as a basis for further implementations to be developed that can interact with existing implementations as well as those to be developed in the future.

Note that the behaviors on which this document are based are each demonstrated by a combination of an NFSv4 server implementation proper and a server-side physical file system. It is common for servers and physical file systems to be configurable as to the behavior shown. In the discussion below, each configuration that shows different behavior is considered separately.

As a consequence of this choice, normative terms defined in [\[RFC2119\]](#) are derived from implementation behavior, rather than the other way around. The specifics are discussed in [Section 2](#).

With regard to the question of interoperability with existing specifications for NFSv4 minor versions, different minor versions pose different issues.

With regard to NFSv4.0 [[RFC7530](#)], no interoperability issues are expected to arise because the internationalization in that specification, which is the basis for this one, was also based on the behavior of existing implementations. Although, in a formal sense, the treatment of internationalization here supersedes that in [[RFC7530](#)], the treatments are intended to be the same in order to eliminate interoperability issues.

With regard to NFSv4.1 [[RFC5661](#)], the situation is quite different. The approach to internationalization specified in that document was never implemented, and implementers were either unaware of the troublesome implications of that approach or chose to ignore the existing specification as essentially unimplementable. An internationalization approach compatible with that specified in [[RFC7530](#)] tended to be followed, despite the fact that, in other respects, NFSv4.1 was treated as a separate protocol.

If there were NFSv4 servers who obeyed the internationalization dictates within [[RFC5661](#)], or clients that expected servers to do so, they would fail to interoperate with typical clients and servers when dealing with non-UTF8 file names, which are quite common. As no such implementation have come to our attention, it has to be assumed that they do not exist and interoperability with existing implementations is an appropriate basis for this document.

2. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as [BCP 14](#) [[RFC2119](#)] [[RFC8174](#)] when, and only when, they appear in all capitals, as shown here.

Although the key words "MUST", "SHOULD", and "MAY" retain their normal meanings, as described above, the fact this specification was derived from existing implementation patterns requires that we explain how the normative terms used derive from the behavior of existing implementations, in those situations in which existing implementation behavior patterns can be determined.

- o Behavior implemented by all existing clients or servers is described using "MUST", since new implementations need to follow existing ones to be assured of interoperability. While it is

possible that different behavior might be workable, we have found no case where this seems reasonable.

The converse holds for "MUST NOT": if a type of behavior poses interoperability problems, it MUST NOT be implemented by any existing clients or servers.

- o Behavior implemented by most existing clients or servers, where that behavior is more desirable than any alternative, is described using "SHOULD", since new implementations need to follow that existing practice unless there are strong reasons to do otherwise.

The converse holds for "SHOULD NOT".

- o Behavior implemented by some, but not all, existing clients or servers is described using "MAY", indicating that new implementations have a choice as to whether they will behave in that way. Thus, new implementations will have the same flexibility that existing ones do.
- o Behavior implemented by all existing clients or servers, so far as is known -- but where there remains some uncertainty as to details -- is described using "should". Such cases primarily concern details of error returns. New implementations should follow existing practice even though such situations generally do not affect interoperability.

There are also cases in which certain server behaviors, while not known to exist, cannot be reliably determined not to exist. In part, this is a consequence of the long period of time that has elapsed since the publication of the defining specifications, resulting in a situation in which those involved in the implementation work may no longer be involved in or aware of working group activities.

In the case of possible server behavior that is neither known to exist nor known not to exist, we use "SHOULD NOT" and "MUST NOT" as follows, and similarly for "SHOULD" and "MUST".

- o In some cases, the potential behavior is not known to exist but is of such a nature that, if it were in fact implemented, interoperability difficulties would be expected and reported, giving us cause to conclude that the potential behavior is not implemented. For such behavior, we use "MUST NOT". Similarly, we use "MUST" to apply to the contrary behavior.
- o In other cases, potential behavior is not known to exist but the behavior, while undesirable, is not of such a nature that we are able to draw any conclusions about its potential existence. In

such cases, we use "SHOULD NOT". Similarly, we use "SHOULD" to apply to the contrary behavior.

In the case of a "MAY", "SHOULD", or "SHOULD NOT" that applies to servers, clients need to be aware that there are servers that may or may not take the specified action, and they need to be prepared for either eventuality.

3. History

The history of internationalization within NFSv4 is discussed in this section. Despite the fact that NFSv4.0 and subsequent minor versions have differed in many ways, the actual implementations of internationalization have remained the same and internationalized names have been handled without regard to the minor version being used. As a result, this document treats internationalization for all NFSv4 minor versions together.

During the period from the publication of [[RFC3010](#)] until now, two different perspectives with regard to internationalization have been held and represented, to varying degrees, in specifications for NFSv4 minor versions.

- o The perspective held by NFSv4 implementers treated internationalization as basically outside the scope of what NFSv4 client and server implementers could deal with. This was because the POSIX interface treated filenames as uninterpreted strings of bytes, because the file systems used by NFSv4 servers treated filenames similarly, and because those file systems contained files with internationalized names using a number of different encoding methods, chosen by the users of the POSIX interface. From this perspective, wider support for internationalized names and general use of universal encodings was a matter for users and applications and not for protocol implementers or designers.
- o Within the IETF in general and in the IESG, there was a feeling that new protocols, such as NFSv4, could not avoid dealing with internationalization issues, making it difficult to treat these matters, as the implementers' perspective would have it, as essentially out of scope.

As specifications were developed, approved, and at times rewritten, this fundamental difference of approach was never fully resolved, although, with the publication of [[RFC7530](#)], a satisfactory *modus vivendi* may have been arrived at.

Although many specifications were published dealing with NFSv4 internationalization, all minor versions used the same implementation

approach, even when the current specification for that minor version specified an entirely different approach. As a result, we need to treat the history of NFSv4 internationalization below as an integrated whole, rather than treating individual minor versions separately.

- o The approach to internationalization specified in [[RFC3010](#)] sidestepped the conflict of approaches cited above by discussing the reasons that UTF-8 encoding was desirable while leaving filenames as uninterpreted strings of bytes. The issue of string normalization was avoided by saying "The NFS version 4 protocol does not mandate the use of a particular normalization form at this time."

Despite this approach's inconsistency with general IETF expectations regarding internationalization, [RFC3010](#) was published as a Proposed Standard. NFSv4.0 implementation related to internationalization followed the same paradigm used by NFSv3, assuring interoperability with files created using that protocol, as well as with those created using local means of file creation.

- o When it became necessary, because of issues with byte-range locking, to create an rfc3010bis, no change to the previously approved approach seemed indicated and the drafts submitted up until [[I-D.ietf-nfsv4-rfc3010bis](#)] closely followed [RFC3010](#) as far as internationalization. The IESG then decided that a different approach to internationalization was required, to be based on stringprep [[RFC3454](#)] and rfc3010bis was accordingly revised, replacing all of the Internationalization section, before being published as [[RFC3530](#)].

These changes required the rejection of file names that were not valid UTF-8, file names that included code points not, at the time of publication, assigned a Unicode character (e.g. capital eszett) or that were not allowed by stringprep (e.g. Zero-width joiner and non-joiner characters). Because these restrictions would have caused the set of valid file names to be different on NFS-mounted and local file systems there was no chance of them ever being implemented.

Because these changes were made without working group involvement, most implementers were unaware of them while those who were aware of the changes ignored them and maintained the internationalization approach specified in [RFC3010](#).

- o When NFSv4.1 was being developed, it seemed that no changes in internationalization would be required. Many people were unaware of the stringprep-based requirements which made the NFSv4.0

internationalization specified in [RFC3530](#) unimplementable. As a result, the internationalization specified in [\[RFC5661\]](#) was the same as that in [RFC3530](#).

As a result, even though NFSv4.1 was a separate protocol and could have had a different approach to internationalization, for a considerable time, internationalization for both protocols was specified to be the same (in [RFC3530](#) and [RFC5661](#)) while the actual implementations of the two minor versions both followed the approach specified in [RFC3010](#), despite its obsoleted status.

- o When work started on rfc3530bis it was clear that issues related to internationalization had to be addressed. When the implications of the stringprep references in [RFC3530](#) were discussed with implementers it became clear that mandating that NFSv4.0 filenames conform to stringprep was not appropriate. While some working group members articulated the view that, because of the need to maintain compatibility with the POSIX interface and existing file systems, internationalization for NFSv4 could not be successfully addressed by the IETF, the rfc3530bis draft submitted to the IESG did not explicitly embrace the implementers' perspective set forth above.

The draft submitted to the IESG and [\[RFC7530\]](#) as published provided an explanation (see [Section 4](#)) as to why restrictions on character encodings were not viable. It allowed non-UTF-8 encodings to be used while defining UTF-8 as the preferred encoding and allowing servers to reject non-UTF-8 string as invalid. Other stringprep-based string restrictions were eliminated. With regard to normalization, it continued to defer the matter, leaving open the possibility that one might be chosen later.

This approach is compatible, in implementation terms, with that specified in [\[RFC3010\]](#), allowing it to be used compatibly with existing implementation for all existing minor versions. This is despite the fact that [\[RFC5661\]](#) specifies an entirely different approach.

As a result of discussions leading up to the publishing of [RFC7530](#), it was discovered that some local file systems used with NFSv4 were configured to be both normalization-aware and normalization-preserving, mapping all canonically equivalent file names to the same file while preserving the form actually used to create the file, of whatever form, normalized or not. This behavior, which is legal according to [RFC3010](#), which says little about name mapping is probably illegal according to stringprep. Nevertheless, it was expressly pointed out in [RFC7530](#) as a valid

choice to deal with normalization issues, since it allows normalization-aware processing without the difficulties that arise in imposing a particular normalization form, as described in [Section 7](#).

- o NFSv4.2 made no changes to internationalization. As a result, [\[RFC7862\]](#) which made no mention of internationalization, implicitly aligned internationalization in NFSv4.2 with that in NFSv4.1, as specified by [\[RFC5661\]](#).

As a result of this implicit alignment, there is no need for this document to specifically address NFSv4.2 or be marked as updating [RFC7862](#). It is sufficient that it updates [RFC5661](#), which specifies the internationalization for NFSv4.1, inherited by NFSv4.2.

The above history, can, for the purposes of the rest of this document be summarized in the following two statements:

- o The actual treatment of internationalization within NFSv4 has not been affected by the particular minor version used, despite the fact that the specifications for the minor versions have often differed in their treatment of internationalization.
- o Implementations have followed the internationalization approach specified in [RFC3010](#), which is compatible with the treatment in [RFC7530](#).

In order to deal with all NFSv4 minor versions, this document follows the internationalization approach defined in [RFC7530](#), in order to maintain compatibility with all existing NFSv4 minor versions. Issues relating to potential future minor versions and protocol extensions are dealt with in [Section 11](#).

4. Limitations on Internationalization-Related Processing in the NFSv4 Context

There are a number of noteworthy circumstances that limit the degree to which internationalization-related encoding and normalization-related restrictions can be universal with regard to NFSv4 clients and servers:

- o The NFSv4 client is part of an extensive set of client-side software components whose design and internal interfaces are not within the IETF's purview, limiting the degree to which a particular character encoding might be made standard.

- o Server-side handling of file component names is typically implemented within a server-side physical file system, whose handling of character encoding and normalization is not specifiable by the IETF.
- o Typical implementation patterns in UNIX systems result in the NFSv4 client having no knowledge of the character encoding being used, which might even vary between processes on the same client system.
- o Users may need access to files stored previously with non-UTF-8 encodings, or with UTF-8 encodings that are not in accord with any particular normalization form.

5. Summary of Server Behavior Types

As mentioned in [Section 8](#), servers MAY reject component name strings that are not valid UTF-8. This leads to a number of types of valid server behavior, as outlined below. When these are combined with the valid normalization-related behaviors as described in [Section 6](#), this leads to the combined behaviors outlined below.

- o Servers that limit file component names within a given file system to UTF-8 strings exist with normalization-related handling as described in [Section 6](#). These are best described as behaving as "UTF-8-only servers".
- o Servers that do not limit file component names on particular file systems to UTF-8 strings are very common and are necessary to deal with clients/applications not oriented to the use of UTF-8. Such servers ignore normalization-related issues, and there is no way for them to implement either normalization or representation-independent lookups. These are best described as behaving as "UTF-8-unaware servers" for such file systems, since they treat file component names as uninterpreted strings of bytes and have no knowledge of the characters represented. See [Section 9](#) for details.
- o It is possible for a server to allow component names that are not valid UTF-8, while still being aware of the structure of UTF-8 strings. Such servers could implement either normalization or representation-independent lookups but apply those techniques only to valid UTF-8 strings. Such servers are not common, but it is possible to configure at least one known server to have this behavior. This behavior SHOULD NOT be used due to the possibility that a filename using one encoding may, by coincidence, have the appearance of a UTF-8 filename; the results of UTF-8 normalization or representation-independent lookups are unlikely to be correct

in all cases, when considered from the viewpoint of the other encoding.

6. String Encoding

Strings that potentially contain characters outside the ASCII range [[RFC20](#)] are generally represented in NFSv4 using the UTF-8 encoding [[RFC3629](#)] of Unicode [[UNICODE](#)]. See [[RFC3629](#)] for precise encoding and decoding rules.

Some details of the protocol treatment depend on the type of string:

- o For strings that are component names, the preferred encoding for any non-ASCII characters is the UTF-8 representation of Unicode.

In many cases, clients have no knowledge of the encoding being used, with the encoding done at the user level under the control of a per-process locale specification. As a result, it may be impossible for the NFSv4 client to enforce the use of UTF-8. The use of non-UTF-8 encodings can be problematic, since it may interfere with access to files stored using other forms of name encoding. Also, normalization-related processing (see [Section 7](#)) of a string not encoded in UTF-8 could result in inappropriate name modification or aliasing. In cases in which one has a non-UTF-8 encoded name that accidentally conforms to UTF-8 rules, substitution of canonically equivalent strings can change the non-UTF-8 encoded name drastically.

The kinds of modification and aliasing mentioned here can lead to both false negatives and false positives, depending on the strings in question, which can result in security issues such as elevation of privilege and denial of service (see [[RFC6943](#)] for further discussion).

- o For strings based on domain names, non-ASCII characters MUST be represented using the UTF-8 encoding of Unicode, and additional string format restrictions apply. See [Section 8](#) for details.
- o The contents of symbolic links (of type linktext4 in the XDR) MUST be treated as opaque data by NFSv4 servers. Although UTF-8 encoding is often used, it need not be. In this respect, the contents of symbolic links are like the contents of regular files in that their encoding is not within the scope of this specification.
- o For other sorts of strings, any non-ASCII characters SHOULD be represented using the UTF-8 encoding of Unicode.

7. Normalization

The client and server operating environments may differ in their policies and operational methods with respect to character normalization (see [\[UNICODE\]](#) for a discussion of normalization forms). This difference may also exist between applications on the same client. This adds to the difficulty of providing a single normalization policy for the protocol that allows for maximal interoperability. This issue is similar to the issues of character case where the server may or may not support case-insensitive filename matching and may or may not preserve the character case when storing filenames. The protocol does not mandate a particular behavior but allows for a range of useful behaviors.

The NFSv4 protocol does not mandate the use of a particular normalization form. A subsequent minor version of the NFSv4 protocol might specify a particular normalization form, although there would be difficulties in doing so (see [Section 11](#) for details). In any case, the server and client can expect that they may receive unnormalized characters within protocol requests and responses. If the operating environment requires normalization, then the implementation will need to normalize the various UTF-8 encoded strings within the protocol before presenting the information to an application (at the client) or local file system (at the server).

Server implementations MAY normalize filenames to conform to a particular normalization form before using the resulting string when looking up or creating a file. Servers MAY also perform normalization-insensitive string comparisons without modifying the names to match a particular normalization form. Except in cases in which component names are excluded from normalization-related handling because they are not valid UTF-8 strings, a server MUST make the same choice (as to whether to normalize or not, the target form of normalization, and whether to do normalization-insensitive string comparisons) in the same way for all accesses to a particular file system. Servers SHOULD NOT reject a filename because it does not conform to a particular normalization form, as this would deny access to clients that use a different normalization form.

8. String Types with Processing Defined by Other Internet Areas

There are two types of strings that NFSv4 deals with that are based on domain names. Processing of such strings is defined by other Internet standards, and hence the processing behavior for such strings should be consistent across all server operating systems and server file systems.

These are as follows:

- o Server names as they appear in the `fs_locations` and `fs_locations_info` attribute. Notes that for most purposes, such server names will only be sent by the server to the client. The exception is the use of these attributes in a `VERIFY` or `NVERIFY` operation.
- o Principal suffixes that are used to denote sets of users and groups, and are in the form of domain names.

The general rules for handling all of these domain-related strings are similar and independent of the role of the sender or receiver as client or server, although the consequences of failure to obey these rules may be different for client or server. The server can report errors when it is sent invalid strings, whereas the client will simply ignore invalid string or use a default value in their place.

The string sent SHOULD be in the form of one or more U-labels as defined by [\[RFC5890\]](#). If that is impractical, it can instead be in the form of one or more LDH labels [\[RFC5890\]](#) or a UTF-8 domain name that contains labels that are not properly formatted U-labels. The receiver needs to be able to accept domain and server names in any of the formats allowed. The server MUST reject, using the error `NFS4ERR_INVALID`, a string that is not valid UTF-8, or that contains an ASCII label that is not a valid LDH label, or that contains an XN-label (begins with "xn--") for which the characters after "xn--" are not valid output of the Punycode algorithm [\[RFC3492\]](#).

When a domain string is part of `id@domain` or `group@domain`, there are two possible approaches:

1. The server treats the domain string as a series of U-labels. In cases where the domain string is a series of A-labels or Non-Reserved LDH (NR-LDH) labels, it converts them to U-labels using the Punycode algorithm [\[RFC3492\]](#). In cases where the domain string is a series of other sorts of LDH labels, the server can use the `ToUnicode` function defined in [\[RFC3490\]](#) to convert the string to a series of labels that generally conform to the U-label syntax. In cases where the domain string is a UTF-8 string that contains non-U-labels, the server can attempt to use the `ToASCII` function defined in [\[RFC3490\]](#) and then the `ToUnicode` function on the string to convert it to a series of labels that generally conform to the U-label syntax. As a result, the domain string returned within a user id on a `GETATTR` may not match that sent when the user id is set using `SETATTR`, although when this happens, the domain will be in the form that generally conforms to the U-label syntax.

2. The server does not attempt to treat the domain string as a series of U-labels; specifically, it does not map a domain string that is not a U-label into a U-label using the methods described above. As a result, the domain string returned on a GETATTR of the user id MUST be the same as that used when setting the user id by the SETATTR.

A server SHOULD use the first method.

For VERIFY and NVERIFY, additional string processing requirements apply to verification of the owner and owner_group attributes; see the section entitled "Interpreting owner and owner_group" for the document specifying the minor version in question ([[RFC7530](#)], [[RFC5661](#)])

9. Errors Related to UTF-8

Where the client sends an invalid UTF-8 string, the server MAY return an NFS4ERR_INVALID error. This includes cases in which inappropriate prefixes are detected and where the count includes trailing bytes that do not constitute a full Multiple-Octet Coded Universal Character Set (UCS) character.

Requirements for server handling of component names that are not valid UTF-8, when a server does not return NFS4ERR_INVALID in response to receiving them, are described in [Section 10](#).

Where the string supplied by the client is not rejected with NFS4ERR_INVALID but contains characters that are not supported by the server as a value for that string (e.g., names containing slashes, or characters that do not fit into 16 bits when converted from UTF-8 to a Unicode codepoint), the server should return an NFS4ERR_BADCHAR error.

Where a UTF-8 string is used as a filename, and the file system, while supporting all of the characters within the name, does not allow that particular name to be used, the server should return the error NFS4ERR_BADNAME. This includes such situations as file system prohibitions of "." and ".." as filenames for certain operations, and similar constraints.

10. Servers That Accept File Component Names That Are Not Valid UTF-8 Strings

As stated previously, servers MAY accept, on all or on some subset of the physical file systems exported, component names that are not valid UTF-8 strings. A typical pattern is for a server to use UTF-8-unaware physical file systems that treat component names as

uninterpreted strings of bytes, rather than having any awareness of the character set being used.

Such servers SHOULD NOT change the stored representation of component names from those received on the wire and SHOULD use an octet-by-octet comparison of component name strings to determine equivalence (as opposed to any broader notion of string comparison). This is because the server has no knowledge of the character encoding being used.

Nonetheless, when such a server uses a broader notion of string equivalence than what is recommended in the preceding paragraph, the following considerations apply:

- o Outside of 7-bit ASCII, string processing that changes string contents is usually specific to a character set and hence is generally unsafe when the character set is unknown. This processing could change the filename in an unexpected fashion, rendering the file inaccessible to the application or client that created or renamed the file and to others expecting the original filename. Hence, such processing should not be performed, because doing so is likely to result in incorrect string modification or aliasing.
- o Unicode normalization is particularly dangerous, as such processing assumes that the string is UTF-8. When that assumption is false because a different character set was used to create the filename, normalization may corrupt the filename with respect to that character set, rendering the file inaccessible to the application that created it and others expecting the original filename. Hence, Unicode normalization SHOULD NOT be performed, because it may cause incorrect string modification or aliasing.

When the above recommendations are not followed, the resulting string modification and aliasing can lead to both false negatives and false positives, depending on the strings in question, which can result in security issues such as elevation of privilege and denial of service (see [[RFC6943](#)] for further discussion).

11. Future Minor Versions and Extensions

As stated above, all current NFSv4 minor versions allow use of non-UTF-8 encodings, allow servers a choice of whether to be aware of normalization issues or not, and allows servers a number of choices about how to address normalization issues. This range of choices reflects the need to accommodate existing file systems and user expectations about character handling which in turn reflect the assumptions of the POSIX model of handling file names.

While it is theoretically possible for a subsequent minor version to change these aspects of the protocol (see [[RFC8178](#)]), this section will explain why any such change is highly unlikely, making it expected that these aspects of NFSv4 internationalization handling will be retained indefinitely. As a result, any new minor version specification document that made such a change would have to be marked as updating or obsoleting this document

No such change could be done as an extension to an existing minor version or in a new minor version consisting only of OPTIONAL features. Such a change could only be done in a new minor version, which like minor version one, was prepared to be incompatible to some degree with the previous minor versions. While it appears unlikely that such minor versions will be adopted, the possibility cannot be excluded, so we need to explore the difficulties of changing the aspects of internationalization handling mentioned above.

- o Establishing UTF-8 as the sole means of encoding for internationalized characters, would make inaccessible existing files stored with other encodings. Further, unless there were a corresponding change in the UNIX file interface model, it would cause the set of valid names for local and remote files to diverge.
- o Imposing a particular normalization form, in the sense of refusing to create to allow access to files whose UTF-8-encoded names are not of the selected normalization form would give rise to similar difficulties.
- o Defining a preferred normalization form to be returned as the names of all internationalized files, would result in applications having to deal with sudden unexplained changes of file names for existing files.

None of the above appears likely since there does not seem to be any corresponding benefits to justify the difficulties that they would create.

There would also be difficulties in otherwise reducing the set of three acceptable normalization handling options, without reducing it to a single option by imposing a specific normalization form.

- o Eliminating the possibility of a single possible normalization form, would pose similar difficulties to imposing the other one, even if representation-independent comparisons were also allowed.

In either case, a specific normalization form would be disfavored, with no corresponding benefit.

- o Allowing only representation-independent lookups would not impose difficulties for clients, but there are reasons to doubt it could be universally implemented, since such name comparisons would have to be done within the file system itself.

Such a change could only be made once support file system support for representation-independent file lookups would become commonly available. As long as the POSIX file naming model continues its sway, that would be unlikely to happen.

One possible internationalization-related extension that the working could adopt would be definition of an OPTIONAL per-fs attribute defining the internationalization-related handling for that file system. That would allow clients to be aware of server choices in this area and could be adopted without disrupting existing clients and servers.

12. IANA Considerations

The current document does not require any actions by IANA.

13. Security Considerations

Unicode in the form of UTF-8 is generally is used for file component names (i.e., both directory and file components). However, other character sets may also be allowed for these names. For the owner and owner_group attributes and other sorts strings whose form is affected by standard outside NFSv4 (see [Section 8.](#)) are always encoded as UTF-8. String processing (e.g., Unicode normalization) raises security concerns for string comparison. See Sections [8](#) and [7](#) as well as the respective Sections [5.9](#) of [\[RFC7530\]](#) and [\[RFC5661\]](#) for further discussion. See [\[RFC6943\]](#) for related identifier comparison security considerations. File component names are identifiers with respect to the identifier comparison discussion in [\[RFC6943\]](#) because they are used to identify the objects to which ACLs are applied (See the respective Sections [6](#) of [\[RFC7530\]](#) and [\[RFC5661\]](#)).

14. References

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